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THE ROUND-LAP BALE SYSTEM FOR BALING COTTON.

[*Being the report of the Franklin Institute, through its Committee on Science and the Arts, on the System of Baling Cotton employed by the American Cotton Company. Referred by the Bureau of Awards of the National Export Exposition. Sub-Committee.—Chas. E. Ronaldson, Chairman; James Christie, M. R. Muckle, Jr., Chas. A. Teal.*]

HALL OF THE FRANKLIN INSTITUTE,

[No. 2118.] PHILADELPHIA, March 1, 1900.

The Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts, acting through its Committee on Science and the Arts, investigating the merits of the American Cotton Company's Round-Lap Bale System, reports as follows:

After a close and careful examination of some detail drawings furnished, your committee has gained a fairly clear understanding of the machine and its product known as round-lap bale cotton. This double press lays up and bales only cotton.

The process may be described concisely as follows:

The cotton, in flakes, as it comes from the gin, is fed up the lint flue (where considerable dust settles in the dust bins in the bottom of this flue) to the condenser (revolving at about fifty turns per minute). At the condenser the remaining dust and dirt are eliminated and carried off through the dust flue overhead. The flakes hold to the cylinder of the condenser but a moment, falling into the bat former, where they are assembled into a smooth, regular-running "bat," which, coming down from the bat former, passes under the compression roll, which compresses the bat only enough to expel the air. Thence it runs down and around the core-shaft, by means of the baling belt, and is wound up, lap around lap, until several layers are run upon the core-shaft, when the baling rolls come into play and the increasing bale moves the movable rolls (attached to the hydraulic pump) back, thus forcing the pump plunger into the cylinder, driving the water up into the air chamber, compressing the air and increasing the pressure. This pressure increases until the bale is about one-third in size, when the maximum pressure is reached and maintained (by means of a relief valve) to the finish of the bale. As the bale nears completion, a bell signals the fact, when the operator throws over the tilting board, which diverts the bat into the other press and a new bale is started. The press holding the bale just completed is stopped; a fine, close-woven burlap is run into position, press started, and burlap wound around the bale till it overlaps. It is then cut to proper length to receive the ends, which are sewn in after the bale has been taken from the press. The air during compression is excluded, not forced out, as is done in compressing a square bale; the fiber is not twisted, and any possibility of destruction of fiber is eliminated; its elasticity remains intact. The fiber remains quiescent upon unrolling a bale, and if there be any expansion, it is very slight, and in the direction of the thickness of the bat and not laterally, indicating that the fibers are not tangled, but lie about parallel to one another. The baling belts are the width of the rolls, and are kept taut by properly-arranged tension rolls.

This round-lap bale is especially worthy of notice, as it presents features possessed by no other bale in the market; that wherever it is to be used, each and every bale can be unrolled clear to the center; also, these bales, as they are unwrapped, can be fed to the lappers without extra hand labor; also that several bales can be unrolled and fed into the lapper at the same time, thus mixing automatically.

Therefore your committee would respectfully call attention to the several points of merit in the double press itself, notably:

(1) The bat former and the method pursued in excluding the air from the cotton while in it, or passing through it to the compression rolls.

(2) The arrangement of rolls to produce the necessary compression upon the bale, whereby the operation of the machine becomes continuous—the device used in encasing the finished bales, in close-woven burlaps.

(3) We would particularly call attention to the round-lap bale, the product of this double press, inasmuch as it is unique. It is simply a continuous roll of cotton, of uniform width, wound under pressure, and, when properly encased, requires no further care, no ties, etc., has a greater uniform density than the square bale of commerce, and far less liability to damage by fire or water, or from any source in transit. It is more convenient to handle, and extremely economical of space. The danger of tampering with the round bales, or of fraudulent practices upon it, are reduced to a minimum, while, when it is used in the mill or factory, a very considerable amount of hand-labor, and consequently expense, is saved.

From a great mass of evidence which the sub-committee has gathered it appears that the round-lap bale system introduced by the American Cotton Company has positively done away with all the objectionable features of the old style "square bale" method of baling cotton, against which the cotton spinners of Europe and America have been protesting for many years most emphatically, and, incidentally, that the new system introduced large economies, the benefits of which are enjoyed by producers and factors, as well as by

the spinners. These economies are conservatively estimated as equivalent to many millions of dollars on the yearly cotton crop, due to the great increase of the commercial importance of the improved system of baling introduced by the American Cotton Company. The highest award in the gift of the Institute is believed to be only a proper recognition of the importance of the revolution in the cotton industry brought about by the introduction of the round-lap bale system, and the award of the Elliott Cresson Medal is accordingly made by the Franklin Institute to the American Cotton Company, of New York.

Furthermore, while the investigation of the sub-committee has been confined nominally to the consideration of the merits of the round-lap bale produced by this company, the investigators deem it proper to embrace in their report a reference to the machine or compress by which the production of this form of baling is made practicable, and without which the system could not have been made technically and commercially successful. The machine in question is admirably adapted for its intended purpose, and it appears to the investigating committee to be eminently proper to emphasize its interest commensurate with the successful operation of the round-lap baling system by some recognition. Accordingly, the award of the John Scott Legacy Premium and Medal is recommended by the Franklin Institute to Magnus Swenson, of Chicago, Ill., for his round-lap baling cotton compress.

Adopted at the stated meeting of the Committee on Science and the Arts, held Wednesday, April 4, 1900.

JOHN BIRKINBINE, *President.*
WM. H. WAHL, *Secretary.*

Countersigned by
H. R. HEYL,
Chairman of the Committee on Science and the Arts.

APPENDIX.

In tracing the history of the round-lap system of baling cotton, the earliest invention distinctly describing a "cylindrical bale" was that of Wm. B. North, of Jersey City, N. J.

(see U. S. patent No. 5,632, of June 13, 1848). This invention described an improvement in cotton presses, the essential features of which consisted of a combination of three rollers so arranged that a line joining their axes would form an equilateral triangle, and which were suspended and weighted in such manner as to be capable of moving apart as the cotton fed between them from the gin accumulated in the form of a round bale. This patent of North may be regarded as the basic patent on the round-lap baling system for cotton.

This invention appears to have attracted no attention, and nothing in this direction appears to have been accomplished of any practical value until the year 1885. In that year, and those closely following, came the inventions of T. M. Workman (No. 331,932, December 8, 1885), H. A. Evans (No. 366,943, July 19, 1887), J. W. Brown (No. 446,128, February 10, 1891), P. L. & W. Brady (No. 378,570, February 28, 1888), J. W. Graves (No. 510,383, 6 and 8, December 5, 1893). None of the inventions here enumerated seems to have found commercial application. Following these came the inventions of W. T. Bessonette, of Temple, Tex., bearing dates as follows: Nos. 492,132, February 21, 1893; 508,909, November 21, 1893, and 541,418, June 18, 1895. These inventions are specially mentioned at this place because it has been claimed that they embody all the essential features of the modern round-lap baling press now commercially used. Investigation shows that the last-mentioned invention of Bessonette is the only one which possesses any similarity to the modern lap-bale press. This patent is for an invention describing a two-roll horizontal press, with three belts extending over only one of the rolls. The records of the Patent Office show that Mr. Bessonette was not the inventor of the horizontal press, so that his only claim to novelty in the patent in question resides in the employment of a plurality of endless belts extending over one of the rolls for the purpose of shaping the bale. This arrangement of parts of a press is entirely impracticable, and, so far as the committee is aware, the press of Bessonette never came into commercial use.

The only presses, of which the committee has knowledge, now commercially used are those of George A. Lowry, of Boston, Mass., and Magnus Swenson, of Chicago, Ill.

THE WELSBACH LIGHT.

[*Being the report of the Franklin Institute, through its Committee on Science and the Arts, on the exhibit of the Welsbach Light Company, of Gloucester City, N. J., referred by the Bureau of Awards of the National Export Exposition. Sub-Committee.—Arthur J. Rowland, Chairman; C. A. Hexamer, Wm. McDevitt, Frank P. Brown, Moses G. Wilder.*]

HALL OF THE FRANKLIN INSTITUTE,
[No. 2130.] PHILADELPHIA, May 2, 1900.

The Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts, acting through its Committee on Science and the Arts, investigating the merits of the Welsbach Light, which was referred to the Committee by the Jury of Awards of the late National Export Exposition, 1899, reports as follows:

The procuring of artificial light by some means other than using the flame of burning carbonaceous material in the ordinary candle, lamp or gas burner, has been the aim of many investigators. As a result of this endeavor, we find on the one hand lamps in which carbon is heated to a point where it gives off light—or becomes incandescent—as by the passage of an electric current through an incandescent filament or arc lamp crater; or, on the other hand, lamps in which the incandescence of certain substances (oxides of certain of the elements for the most part) is produced by the application of a heating flame or the passage of an electric current to raise their temperature. Of these latter burners, the development of those using a heating flame applied to produce incandescence of rare earths is the particular thing dealt with in this report, but it seems impossible to avoid a mention of others when giving an outline of the chain of discoveries and inventions leading up to the Welsbach light of to-day.

It is probable that Drummond is one of the earliest discoverers of the fact that heated oxides of certain elements incandesce. Certainly he made the first practical application of the fact. Every one knows of the Drummond or lime light which has been so commonly used in the projection lantern. A piece of lime, or better, a piece of oxide of magnesium, or, most refractory of all, a piece of oxide of zirconium, has an oxyhydrogen flame play upon it and is thereby heated to a temperature at which it incandesces and gives off an intensely-bright white light. Lieutenant Thomas Drummond, in the English government service, made this discovery in 1826, and used it in connection with his heliostat in surveying work, and afterwards proposed the same arrangement for lighthouse service.

In 1868, Le Roux, Professor at École Polytechnique, Paris, discovered that a brilliant incandescent light might be procured from a rod of lime or magnesia, by heating it until an electric current passes, this afterward maintaining the light.

In 1879, Jablochkoff patented the use of a piece of kaolin as a source of light, making it incandesce by passing an electric current through it. He had noticed that the kaolin he had placed between the carbons of his arc lamp assisted the illumination.

These inventions show something of the development of knowledge regarding materials which might be made incandescent, and the means taken to make them incandesce.

Several years later, in 1881, W. M. Jackson (an American) invented the device of a lamp made of platinum, iridium or other materials non-oxidizable at high temperatures, in the form of wires of small section which were heated to incandescence by the use of a heating flame. He discovered that the finer his wires, the more intense the light produced. Here is a beginning of a mantle light.

In 1881, Charles M. Lungren, of New York, patented in the U. S. Patent Office an improvement in illuminating apparatus, which consisted in passing a non-luminous gas flame through a heater of clay or similar material highly

heated by jets of the non-luminous gas, and forcing atmospheric air through the heater and causing it to mingle with the non-luminous gas issuing in one or more jet flames against lime, magnesia, zirconia or similar material, producing incandescence.

In the same year (1881) Mr. Lungren filed an application in the Patent Office for a means of illumination which consisted in forming a filamentary body of refractory material, said body having the structural form necessary to envelope a gas flame and to be rendered incandescent by such flame.

This application, after allowance by the Patent Office, was permitted to lapse, and no patent was then issued.

Mr. Lungren, however, renewed his application in August, 1885, and the patent, which embodied improvements upon his unissued patent of 1881, was issued July 5, 1887 (No. 365,832). Subsequently, a second patent (No. 367,534), describing specific features of his incandescent lighting method, was issued to Lungren under date of August 2, 1887.

In the first of these patents Lungren describes his method of making refractory filaments for lighting composed of "lime, magnesia, zirconia, etc.," by preparing a plastic mass of these materials, or mixtures of them by kneading them with water, or preferably, a solution of a mucilaginous binding material, such as glue or gum, or other combustible material which will be consumed in the further treatment of the filament. When the mass is of the proper consistence, it is put in a press and the filament is obtained by expressing the material through a die. Immediately after their formation, and while still moist, the filaments are formed up into various shapes desired by bending or coiling over a mandrel of wood coated with plumbago, or other device, and then dried, when they are ready to apply to a support and to be used in connection with a gas flame, in substantially the same manner as the well-known Welsbach mantle.

The Lungren incandescent lighting system was the subject of investigation by the Committee on Science and the Arts of the Franklin Institute in 1891. Prolonged practical

tests of the Lungren filaments showed that they possessed unusual life duration in service, with satisfactory lighting quality, and the award of the John Scott Legacy Premium and Medal was made to the inventor.

For reasons unknown to your committee, this promising invention was never commercially exploited.

The next year (1882) a Frenchman, Charles Clamond, invented a lime light operated without oxyhydrogen flame by intensely heating the air used and directing the flame of his air and gas mixture against the refractory oxide chosen. He knew of the possible use of certain other metallic oxides to produce an incandescent light, and even invented a basket or mantle of magnesia threads, supported in an enclosing platinum mantle of small wire and large mesh, which was hung below the lamp and the heating flame directed down into it. The threads were made from magnesia which was calcined and pulverized, then made plastic by mixing with salts of magnesia, which may be afterwards decomposed by heat, then squirted through a die, woven into a basket form and dried and baked.

In 1885, Otto B. Fahnehjelm, a Swedish inventor, secured an American patent (see U. S. Patent No. 312,452, February 17, 1885) for an incandescent light which consisted in the combination with a suitable gas burner and a shade holder of means for suspending an incandescent body in the flame of the burner, and for adjusting the incandescing body horizontally and vertically in relation to the flame. The Fahnehjelm light consisted substantially of a series of rods of calcined magnesia, resembling the teeth of a comb, held in a suitable frame and suspended in a non-luminous flame of gas.

In 1886, Galopin and Evans (in Australia) produced a lamp burning hydrocarbon vapor mixed with air to produce a heating flame, directed downwards into a woven platinum mantle, which was thus made incandescent.

About this same time, or even a little earlier (1885), Carl Auer von Welsbach announced the invention of a lamp in which the rare oxides of lanthanum, yttrium, zirconium, etc., in a finely divided condition, were rendered incandes-

cent by heating to a high temperature. The source of light was a light network of cotton thread impregnated with a solution of the salts of the combined nitrates, oxides or bromides. After being saturated with these, upon exposure to heat, the supporting cotton network was burned out, the salts converted into the oxides and a skeleton hood or cap thus prepared, which would incandesce when a heating flame was applied to it.

The absolute originality of this form of mantle and method of manufacture should be carefully noted.

The nitrates of the metals, being very soluble, were especially adapted to the process, although sulphates, iodides or bromides could also be used.

Welsbach found that this mantle, as it came to be called almost from the first, could resist the action of all atmospheric air fit to breathe for an indefinite length of time, was not changed by exposure and would remain effective for a long time.

For the next five years or more von Welsbach was constantly at work making elaborate investigation of the properties of all oxides of metals which would incandesce when used separately, and when combined in various mixtures. He invented processes whereby the salts of the metals required for impregnating mantles might be prepared from the natural ores, originated means for strengthening the frail mantle, arranged the mantles for transportation in safety, and perfected many details making the lamp practical.

It is interesting to notice that the form of mantle and the general process of manufacture have remained up to the present precisely as von Welsbach originally planned them, without improvements or essential modification of any kind.

One or two of the discoveries of von Welsbach are necessarily mentioned a little in detail, to explain the magnitude of the investigations he conducted and the sort of results he procured.

A patent No. 409,531, August 20, 1889, explains that the illuminating power is greatly increased by adding thorium

oxide; that lanthanum oxide without sufficient thorium oxide crumbles when incandescent—with it the mantle becomes flexible. Later he found (patent No. 563,524) that thorium oxide, by the addition of a small per cent. of uranium or cerium oxide, has a very high illuminating power, producing a vivid and nearly white incandescent light, in spite of the fact that thorium oxide alone radiates little light which is yellow in color, and that uranium oxide alone radiates little light, and it is yellow reddish. Still later, he discovered that the illuminating power of lanthanum, cerium, yttrium, zirconium and other metals of the refractory earths is greatly increased by the addition of thorium oxide (ThO_2); that cerium not only gives a yellow light (very desirable color), but greatly increases the life of the mantle, causes it to hold its shape better, and makes it in every way stronger and more durable.

Thus we get a slight idea of the elaborate researches conducted by Dr. von Welsbach, and of the many difficulties which had to be overcome before the Welsbach mantle could become practical and commercial.

To complete the story of lights procured by the incandescence of metallic oxides, mention should be made of the lamp invented by Prof. Walther Nernst, of the University of Göttingen, early in 1899, the substance rendered incandescent being a magnesia rod through which an electric current is passed after preliminary heating. Not only is this light related to the same group as the Welsbach, not only does it give a very modern illustration of a sort of lamp mentioned earlier in the report, but (most interesting of all) in his latest work Nernst gives up the magnesia and uses the same mixtures of oxides as used in the Welsbach mantle—zirconium, thorium, cerium, erbium, etc.

A very brief description of the lamp and mantle made for use with illuminating gas by the Welsbach Light Company, of Gloucester, N. J., will give the best idea of present methods, and serve to bring out some important points with reference to the light-giving power, durability and economy of the mantle as put on the American market. The Welsbach "J" mantles (standard until very recently)

were made about as follows: A six-cord cotton thread was woven on a knitting machine forming a tube of knitted fabric of rather open mesh. This web has the grease and dirt thoroughly washed out of it, is dried, then cut into lengths double that required for a single mantle. It is then saturated in the fluid (described later), wrung out, stretched over spools and dried. Next, the double length pieces are cut into two, the tops of each piece doubled back and sewed with a platinum wire which draws the top in and provides a means of supporting the mantle when finished from the wire holder. After stretching the mantle over a form, smoothing it down and fastening the platinum wire to the wire mantle holder, the mantle is burned out by touching a Bunsen burner to the top. The cotton burns off slowly, leaving a skeleton mantle of metallic oxides, which are unconsumed, and which preserve the exact shape and detail of every cotton fiber. The soft oxides are then hardened by a Bunsen flame. During burning out and hardening, considerable shrinking takes place. This finishes the process, except the immersion of the mantle in crystalline, to prepare it for transportation, after which it is trimmed and packed. The fluid in which the cotton webbing is immersed is procured from monazite sand, which yields in the finished mantle oxides of thorium and cerium.

The candle-power of mantles of the sort mentioned is about 75 initial candle-power under gas pressure of Philadelphia illuminating gas. This means 20 candles per cubic foot per hour (an ordinary 8-foot fish tail burner gives not over 3 candle-power per cubic foot per hour). The life of the mantles is probably not much below 1,000 hours. The candle-power drops quite rapidly at first and more gradually afterwards, going as low as to one-half the initial candle-power before the mantle breaks.

It is hard to tell how much the perfection of detail in burner construction, a proper selection of chimney, and artistic features of design have contributed to procure the very large commercial use of the lamps. Without proper burners the mantle would be of small value. The details of the common burner, the peculiarities of which make it

different from the ordinary Bunsen burner in adjustment of gas and air; the gauge distributing device to spread the flame over the whole mantle and so fill the mantle are too well known to merit detailed description.

The mantle first made in America, in 1888, gave only 35–40 candle-power initial, under 10/10 pressure, using 3 to 3·2 feet of gas on 3-inch mantles, and under ordinary conditions not over 8 candle-power per cubic foot of gas used.

The new mantle, known as Balm Hill or, popularly, "Yusea" mantle, has a much more open mesh than the "J" mantle, and is made on lace-making machinery. It is thus supposed to be much stronger than the older mantle, and gives about 100 initial candle-power at the mantle when the gas and air are properly adjusted in the burner. Your committee has been unable to gather data of life or decline in candle-power in time to include them in this report.

Certain defects in the mantle light should not be entirely passed over. The mantle is exceedingly fragile and cannot be made to stand where it is subject to continued vibration; the quality of the light is such as to require the adjectives cold, ghastly, harsh, in describing it; and often a greenish tinge in the light is evident. The candle-power drops badly early in the life of a mantle, and is especially subject to this trouble where there is much dust in the air; the oxides seem to volatilize slowly from the mantles, as evidenced by the shrinking in size of strands of mantle and the white deposit on chimney, for platinum melts easily in the part of the flame where the mantles hang.

If the mantle breaks, a hole being thus produced in it, the hot flame strikes out through this, often breaking the chimney and as a secondary result destroying the mantle itself.

On the other hand, the advantages in the use of the mantle for lighting are shown not only by statements already made, but also by the fact that artificial lighting has been profoundly affected by the commercially-successful mantle. We have systems of lighting using mantles now in which the source of the heating flame is gas, gasoline, kerosene. There are systems using Welsbach mantles in

which pressure of large amount, and others in which low pressure is used. There are two great companies, the Welsbach Commercial Company and the Welsbach Street Lighting Company, that do an enormous business and deal only with the use of the Welsbach mantle in lamps using ordinary illuminating gas.

The patents held in this country by the Welsbach Light Company are very broad and fundamental, and have to do with all sorts of details of the system as well. The numbers of the patents of most importance are given below.* Over fifty in all were submitted to your committee. Some of these are not to Welsbach, and yet are for processes of importance in the manufacture of the present American-made mantle and lamp.

In consideration of the enormous advance in the art of artificial lighting made possible by the invention of the Welsbach mantle, the Franklin Institute awards the Elliott Cresson Medal to Dr. Carl Auer von Welsbach, of Vienna, Austria, for his discoveries regarding the metallic oxides which may become incandescent when heated, and for the invention of a mantle by the use of which these metallic oxides are commercially available as sources of artificial light.

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*359,524, March 15, 1887. Carl Auer von Welsbach.
377,698, Feb. 7, 1888. " " " "
377,699, " 7, " " " " "
377,700, " 7, " " " " "
377,701, " 7, " " " " "
390,057, Sept. 25, " Harold J. Bell.
396,347, Jan. 15, 1889. Carl Auer von Welsbach.
399,174, March 5, " " " " "
403,803, May 21, " " " " "
403,804, " 21, " " " " "
407,963, July 30, " F. L. Rawson and W. Stepney Rawson.
409,528, Aug. 20, " Carl Auer von Welsbach.
409,529, " 20, " " " " "
409,530, " 20, " " " " "
409,531, " 20, " " " " "
438,125, Oct. 7, 1890. " " " "
463,470, Nov. 17, 1892. " " " "
563,524, July 7, 1896. " " " "
26,075 (design), Sept. 22, 1896. Geo. S. Barrows.

Also, in view of the many details wrought out by the Welsbach Light Company, of Gloucester, N. J., in putting a thoroughly practical mantle on the market, the Franklin Institute awards to them, the said company, in addition, the Edward Longstreth Medal of Merit.

Adopted at the stated meeting of the Committee on Science and the Arts, held Wednesday, June 6, 1900.

JOHN BIRKINBINE, *President.*
WM. H. WAHL, *Secretary.*

Countersigned by
H. R. HEYL,
Chairman of the Committee on Science and the Arts.

CHEMICAL SECTION.

Stated Meeting, October 25, 1900.

THE USE OF BLAST FURNACE GASES IN GAS ENGINES.

BY PROF. JOSEPH W. RICHARDS,
Member of the Institute.

Practical gas engines were first put into operation by Otto, in 1870. They were for many years made only of small powers, 1 to 10 or, at most, 20 horse-power. The fuel used was illuminating gas, which has the high calorific power of 4,500 to 5,000 calories per cubic meter. About 1886, experiments showed that weaker gas could be used, and that if the gas and air mixture was strongly compressed in the cylinder before explosion, the ignition never failed. This gave rise to the running of gas engines by producer gas, particularly that made by the auxiliary use of steam, and therefore carrying considerable hydrogen. Such gas is in reality a mixture of normal producer gas with water gas; it is sometimes called Dowson gas, after the Dowson producer. It may carry 5 to 15 per cent. of hydrogen, and its calorific power vary between 1,000 and 1,500 calories per cubic meter. The use of this gas in large engines, up to 200 horse-power, gave an efficiency of 1

horse-power per 1 pound of coal per hour, and is even at present the most efficient method of generating mechanical power from coal.

The next step was a natural one; it was a consideration of the question: "Can blast furnace gases be used in gas engines?" As far as I can find, the question was first taken up practically by B. H. Thwaite, a British engineer, in 1894. Before considering his investigations, let us imagine the conditions which bear on the case.

(1) Blast furnace gases are not as rich as illuminating gas or even as producer gas, not even as rich as the poorest regular producer gas. Average analyses of rich and poor producer gas and blast furnace gases would be about as follows, in percentages by volume; on dried gas:

	Dowson Gas.	Siemens Gas.	Blast Furnace Gas.
Hydrogen	8	2	2
Hydrocarbons	2	2	2
Carbonic oxide	33	28	24
Carbonic acid	3	3	12
Nitrogen	58	65	60
Percentage of combustibles	43	32	28
Calorific power per cubic meter	1,400	1,100	950

The conclusions drawn from this comparison would be that it would be a more difficult problem to secure unfailing ignition of blast furnace gases. Indeed, the quality of these gases varies at times so greatly that they can scarcely be burnt under boilers. Any use of these gases in gas engines must therefore face this possibility of very poor gas, and provide exceptional means to secure unfailing ignition of very poor mixtures. Another incidental conclusion would have been that for a given power the engines using blast furnace gas must be larger, because of the decreased calorific power of the gases.

(2) Blast furnace gases are very dusty, from particles of the charge, and impure with metallic and saline vapors. Any prospective use in gas engines must consider this difficulty, and either provide for efficient cleaning of the gas, or provide an engine which is not affected by the dust or corroded

by the saline vapors. Cleaning of the gas would naturally recommend itself as the most likely to succeed in overcoming this obstacle.

(3) There is usually 5 to 10 per cent. of vapor of water in blast furnace gases, which would decrease the expansive force of the explosion and so decrease the power of the engine. A removal of the water vapor by condensation would appear desirable.

(4) Gas engines run ordinarily at 200 revolutions per minute, or more, while blowing engine cylinders run at 25 to 40. Gas engines, therefore, would not appear capable of supplying blast for furnaces without using gearing or other means of reducing the speed, or else by making a radical reduction in the speed of running the engines or a radical increase in the speed of the blowing cylinder. Meanwhile, until these are attained, the gas engines are suited only for higher speed machinery than blowing engines.

Such as above outlined would have been the conditions and problems confronting the investigator in this field six years ago. We will now pass on to consider how these difficulties, real and prospective, have been overcome.

B. H. Thwaite applied for a British patent on May 2, 1894 (granted May 2, 1895, No. 8670), which described methods of purifying blast furnace gas preliminary to using it in gas engines; the methods being, briefly, to take the gases from the furnace in such a manner that as little dust and metallic vapor passes into the down-comer as is possible, and as much combustible gas; then filtering the gas through wet columns of coke or brushwood, and screening it through sawdust, powdered asbestos or a fine wire screen. The claims are for using the special purifying apparatus described, in combination with thermo-dynamic motors, etc.

Mr. J. Riley* says that he was acquainted with this proposal of Thwaite in the autumn of 1894, and in February, 1895, arranged for a 15 horse-power engine to be set at work on gas thus purified, at Wishaw, Scotland. This motor ran some light machinery very successfully, and

* *Journal Iron and Steel Inst.*, 1898, I, 33.

delivered in indicated horse-power the equivalent of 20 per cent. of the thermal value of the gases burnt. This was the first motor run on blast furnace gas. Its successful operation inspired W. H. Watkinson to read a paper on the subject before the West of Scotland Iron and Steel Institute, on March 15, 1895,* in which he discusses the power to be saved by a furnace making 100 tons of pig iron a day, as something like 6,000 horse-power, an amount quite startling, and, it must be said, much too large. The average saving will be about one-half that amount. Still, this is the first public announcement of the successful experiment and of the possibilities which it revealed.

Since 1895, numerous small motors have been in operation in Great Britain, using purified blast furnace gas. They have been mostly of 10 to 40 horse-power, but more recently up to 200, driving machinery and dynamos, but not blowing engines. In the development of large motors and their adaptation to blowing engines the Continent, and more particularly Belgium, has taken the lead.

In the beginning of 1895 experiments were also undertaken in France with small Debouttéville gas engines, but without much success, so that no records of the results attained were made public. Bailly and Kraft, however, engineers at the John Cockerill Works, at Seraing, Belgium, were sanguine of success, and installed a 4 horse-power Debouttéville motor, which began operations in December of that year, being nearly ten months after Thwaite's success in England. This motor worked steadily for eighteen months, an average of sixteen hours daily, using purified blast furnace gas. The analyses of Witz showed that the quality of the gases did not vary so much as had been anticipated, and rather approximate measurements of the efficiency showed a total of 12 per cent. After four months' running the cylinder was found to be clean, it appearing that the dust in the gases was all thrown out in the white smoke of the exhaust. No corrosive action in the cylinder was observed after two years' use.

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* *Journal Iron and Steel Inst.*, 1895, II, 471.

Encouraged by these results, drawings were prepared in 1897 for a 200 horse-power motor of the "Simplex" single-cylinder type, a four-cycle machine. This engine was put in operation in April, 1898, and a description of its installation given by Mr. A. Greiner, Director-General of the Cockerill Society, before the Iron and Steel Institute, on May 5, 1898;* while a report on its working was made by Witz to the same society August 26, 1898.† Greiner said in his announcement: "When a 200 horse-power engine has run successfully for six months, manufacturers will be emboldened to put up one of 500 or 800 horse-power to drive the blowing engines for a blast furnace or converter plant, and thence to a rolling mill engine is an easy advance."

The report of Witz, three months later, was eminently favorable. The tests had been made by Witz, together with Professor Hubert, of Liege University, engineers Bailly and Kraft, of the Cockerill Company, and Debouteville, the gas engine builder. The gas was passed through three pairs of coke scrubbers, and then straight to the engine through a gas holder of 300 cubic meters capacity. Its calorific power varied from 800 to 1,000 calories, and averaged 981 per cubic meter. The cylinder was 0·8 meter diameter by 1·0 meter stroke, and the gas-air mixture was compressed to 7·5 atmospheres pressure before ignition. Fly-wheel, 15 tons. The detailed figures obtained were for a 24-hour run:

Average velocity	105·2 revolutions per minute.
Effective horse-power	181·2
Water used in cylinder jacket	72·0 kilos per horse-power hour.
Oil used for lubricating	15· grams per horse-power hour.
Grease used for lubricating	2·3 " " " "
Temperature of water raised	11·0° C.
" " discharge	480° to 510° C.
Consumption of gas	3·33 m^3 per horse-power hour,
Thermal efficiency	19·5 per cent.

The report remarks that "the engine works as regularly as a steam engine, and the dust in the gas is in no way injurious to its continual operation."

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* *Journal Iron and Steel Institute*, 1898, I, 21.
† *Journal Iron and Steel Institute*, 1898, II, 130.

This engine has been steadily at work now for over two years, driving a dynamo for power purposes day and night, without any wearing out of the parts, the interior of the cylinder showing only a very thin brown skin, which in no wise affects the working of the piston or the efficiency.

Calculations based on the figures obtained with this engine showed that at the Seraing furnaces, making 600 tons of pig iron daily, the gases were producing through steam boilers and engines 2,300 horse-power, with a thermal efficiency of 2·5 per cent. The same gases used in gas engines at an efficiency of 20 per cent. would be capable of developing 18,400 horse-power, leaving a surplus of 16,000 horse-power available for other purposes, which is at the rate of 2,667 horse-power surplus per 100 tons of pig iron made per day.

These surprising figures and the success already achieved stimulated experiments in Hoerde, Germany, and Differdingen, Luxembourg. At Hoerde the Deutz motor was tried, and at Differdingen a "Simplex" engine. The Cockerill Company, however, again took the initiative, and, in 1899, had constructed the largest single-cylinder gas engine ever built, connected to a blowing cylinder for furnishing blast. The engine was designed and constructed by Deboutteville, and was started on November 2, 1899. On May 9, 1900, Mr. A. Greiner described the engine to the Iron and Steel Institute,* and gave the results attained by six months' continuous working. The details are highly interesting, since this is the first gas engine to run the blowing machinery of its own furnace. They are, in abstract, as follows:

DIMENSIONS.

Diameter gas cylinder	1·3 meters (51 inches).
Stroke " "	1·4 " (55 ").
Speed	80 r. p. m. normally.

PRESSURE OF BLAST SUPPLIED.

At 84 r. p. m.	40 centimeters of mercury (7 75 lbs. per in.).
" 94 " "	45 " " " (8·75 " " ").
" 62 " "	62 " " " (12·0 " " ").

Journal Iron and Steel Institute, 1900, I, 109.

POWER DEVELOPED.

561 to 725 effective horse-power in the blast cylinder.

GAS USED.

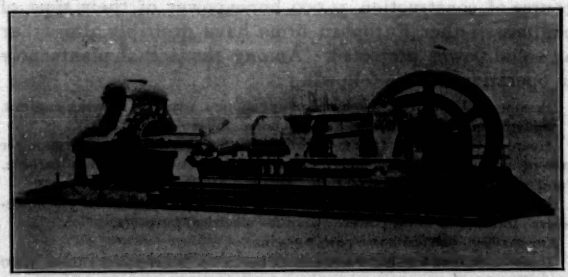
2·86 m³ per effective horse-power hour.
2·33 m³ " indicated " "

EFFICIENCY.

28·7 per cent. as indicated horse-power.

A consideration of the distribution of the heat energy showed approximately:

Converted into work in the cylinder	30 per cent.
Carried away by the cooling water	50 " "
" " in the escaping gases	20 " "



The Cockerill 700 horse-power gas engine and blowing cylinder at the Paris Exposition of 1900.

These tests were conducted by Professor Hubert, of Liege; Mr. Witz, of Lille; Mr. Bryan Donkin, of London; Professor Meyer, of Göttingen, and Professor Dwelshauvers, of Liege. Taking the tests, together with the fact that the engine has actually been blowing a blast furnace for nearly a year, and the question which was proposed by Thwaite has its complete and satisfactory solution. In five short years the problem has been practically solved, and an economic revolution in the working of blast furnaces is but the matter of application of the results already proved possible.

The large engine and blower shown by this company at the Paris Exposition was a duplicate of the one under dis-

cussion. It is rated at 700 horse-power on blast furnace gas, 800 on producer gas and 1,000 on illuminating gas. It was run daily for an hour, and was always surrounded by an interested group of sight-seers. Its approximate cost is given at less than $30,000, or, roughly, $40 per horse-power. This is not far from that of modern steam blowing engines, leaving out the cost of boilers and their maintenance. One may also imagine the possibility of rebuilding our horizontal blowing engines, with their steam and blast cylinders tandem, into gas engines, by replacing the steam cylinder by a gas cylinder and making the blast cylinder quicker acting.

The Cockerill Company and its concessionaries have in course of construction 35,000 horse-power of their type of engines. Other European firms have probably altogether an equal power projected. Among the actual plants now in operation are the following:

Seraing, Belgium, four 500 horse-power motors, running blowing engines.

Differdingen, Luxembourg, four 500 horse-power motors.

Hoerde, Westphalia, two 600 horse-power and two 1,000 horse-power motors, running dynamos and therewith manufacturing calcium carbide. Total, 3,200 horse-power.

Friedenshütte, in Upper Silesia, two 200 horse-power and two 300 horse-power; total, 1,000 horse-power. Used for electrical purposes.

Oberhausen, one 600 horse-power engine.

Dudelingen, two 600 horse-power and two 1,000 horse-power; total, 3,200 horse-power.

Kneutingen, two 500 horse-power for blowing.

Roechling, one 200 horse-power, two 600 horse-power.

Ruhrort, one 500 horse-power.

Barrow, England, 1,000 horse-power.

Toula, near Moscow, three 600 horse-power engines for blowing, and three 200 horse-power engines to run an electric plant; total, 2,400 horse-power.

Island of Elba, 1,000 horse-power.

In order to discuss the application of this great economy to American blast furnace practice, we must confess, to start with, that not one single example can be yet cited. Why this is so is hard to surmise; many reasons, or, rather, excuses, may be advanced; possibly our iron works have been so busy making money during the last two years that they have had no leisure to consider the question fairly and on its merits.

European practice, to start with, provides us with all the data necessary for discussing the question of applying this improvement to American blast-furnace practice. To bring out the great saving of power possible under the different conditions which may prevail in different localities and in different practices of driving furnaces, I have calculated the minimum, the average and the maximum surplus of power which may be obtained by replacing our present boiler and steam engine plants by gas engine plants. The calculations are all made on the basis of a production of 100 metric tons (98·57 long tons) of pig iron produced per day.

CASE I.—*To find the minimum surplus power.* Let us assume:

(1) A poor gas, ratio CO_2 to CO = 3 to 5 (by volume), with the composition by volume—

CO_2	15
CO	25
H	2
CH_4	1
N	57

(2) A very low fuel consumption of 700 kilos per ton of iron (1,550 pounds).

(3) A high temperature of the blast, 700° C.

(4) The requisite quantity of blast supplied at a maximum pressure of 1·33 atmospheres (nearly 20 pounds per square inch).

(5) The hot-blast stoves to have a minimum efficiency (50 per cent.) and therefore to take away a maximum proportion of the gases.

CASE II.—*To find the average surplus power.* Let us assume:

(1) An average gas, with CO_2 to CO = 1 to 2, by volume, and composition by volume—

CO_2	12
CO	24
H	2
CH_4	2
N	60

(2) An average fuel consumption of 900 kilos per ton of iron (2,000 pounds per long ton).

(3) An average temperature of blast, 550° C.

(4) The requisite blast supplied at 0·67 atmosphere (10 pounds per square inch).

(5) The hot-blast stoves to have average efficiency (65 per cent.).

CASE III.—*To find a maximum of surplus power.* Let us assume:

(1) A rich gas, with CO_2 to CO = 1 to 5, by volume, and composition by volume—

CO_2	6·0
CO	30·0
H	0·5
CH_4	0·5
N	63·0

(2) A maximum fuel consumption of 1,045 kilos per ton of pig iron (2,400 pounds per long ton).

(3) A minimum temperature of blast, 400° C.

(4) The requisite blast supplied at a minimum pressure, 0·33 atmosphere (5 pounds per square inch).

(5) The hot-blast stoves to have a maximum efficiency (80 per cent.).

We shall then obtain by the proper calculations the following results as to the surplus power obtainable by using boilers and steam engines on the one hand, or gas engines on the other:

	Case I.	Case II.	Case III.
Volume of gases per 100 k. of iron in m^3	307	404	503
Calorific power of gas per m^3	900	953	986
Calorific power of gas per 100 k. of iron	276,300	385,012	495,958
Assume 10 per cent. lost by leakage	27,630	38,501	49,596
Net power of remaining gas	248,670	346,511	446,362
Weight of blast, in kilos, per 100 k. of pig iron	312	388	462
Volume of blast, in m^3, per 100 k. of pig iron	241	300	357
Heat units in the blast	80,210	60,900	48,362
Heat to be supplied the ovens	160,460	93,700	60,450
Net calorific power of the gas left over for boilers or gas engines	88,210	252,810	385,910
Equivalent horse-power of above gas, at an efficiency of 100 per cent., expressed per 100 tons of pig iron produced daily	5,770	16,500	25,200
Indicated horse-power developable by gas engines using this gas at an efficiency of 30 per cent.	1,730	4,950	7,560
Indicated horse-power necessary for furnishing the blast, plus 10 per cent. for hoisting, pumping, etc.	640	460	270
Surplus indicated horse-power, using gas engines, per 100 tons of pig iron produced daily	1,090	4,490	7,290

Remarks.—The surplus of 1,090 horse-power obtainable in Case I is obtainable, according to the assumptions made,

when all the conditions are the most unfavorable for the generation of power from the gases. These assumptions agree with the best modern practice in all points except the last, *i. e.*, the minimum efficiency of the stoves. It needs no argument to prove that a plant using the minimum of fuel and maximum temperature and pressure of blast would be necessarily a plant with stoves of the most approved type and efficient working. If we were to make this one change in the assumptions, and assume that instead of using stoves with an efficiency of only 50 per cent., there were used modern stoves with 75 per cent. efficiency, there would result a theoretical development of 2,780 horse-power in the gas engines, or a surplus above that required for the furnace itself of 2,140 horse-power. This, then, is the final estimate of the minimum surplus power to be obtained from a modern blast furnace running on the most economical conditions as regards the production of pig iron—reckoned per 100 tons of pig iron daily.

Case II gives a figure which applies, not to the latest type of furnace practice, but to the average type of furnace making 100 to 200 tons of iron per day—such furnaces as represented good working twenty years ago, and many of which are in operation yet east of the Alleghenies.

Case III represents a figure which is approximated by small, old-fashioned furnaces with a high fuel consumption—in other words, average practice of thirty or forty years ago. The one exception to be taken to this statement is that the stoves are assumed to have a maximum efficiency. If they have a minimum efficiency, the figure would be cut down some; but it is only a rough approximation at the best, and an actual illustration to be given will show that it is not higher than has occurred in actual practice.

To prove the correctness of these general conclusions, it will be interesting to check the figures as to horse-power by calculating the power actually raised by steam boilers and engines, and seeing if this coincides with actual results of practice. To do this we will take the surplus gas and assume it thus converted into mechanical

power, at a total efficiency of 3 per cent. (average poor practice), 6 per cent. (average good practice) and 12 per cent. (best attainable practice).

		Case I (*a*).	Case I (*b*).	Case II.	Case III.
Horse-power of gases per 100 tons of pig iron daily, at 100 per cent. efficiency		5,770	9,260	16,500	25,200
Indicated horse-power necessary for running the furnace, per 100 tons daily		640	640	460	270
(1)	Indicated horse-power by steam power at 12 per cent. efficiency	690	1,110	1,980	3,000
	Surplus power, on this assumption	50	470	1,520	2,730
(2)	Indicated horse-power by steam at 6 per cent. efficiency	345	555	990	1,500
	Surplus power, on this assumption	[− 295]	[− 85]	430	1,230
(3)	Indicated horse-power by steam at 3 per cent. efficiency	170	280	495	750
	Surplus power, on this assumption	[− 470]	[− 360]	35	480

Case I (*a*) represents Case I of the previous calculations, *i. e.*, best modern practice with *poor* stoves. Case I (*b*) is the modification which considers best modern practice, using good efficient stoves.

The figures of assumption (1) above are highly theoretical, inasmuch as they represent the very best attainable practice with the best engines and boilers, kept up to their highest efficiency. These figures parallel those of Mr. Gordon, calculated on this assumption, contained in his paper in the *Iron Age*, of October 18, 1900. Considering the difficulties of blast furnace practice, they are an unattainable ideal. They show a moderate surplus in the case of best modern practice, and a large surplus of 1,520 horse-power in the case of average practice.

The figures of assumption (2) really represent nearly the best of modern furnace attainment. They show just about sufficient power raised to run the furnace in good practice with low fuel consumption, and a modest surplus of 430 horse-power in average practice.

The assumption (3) is nearer the average of small blast furnace steam plant efficiency, and shows a decided deficit of power for good running with low fuel consumption, and just barely sufficient power in the average running.

We will close by making some specific applications of these calculations to actual American practice, in order to check off the general reliability of the conclusions so far stated.

CASE III.—As an interesting illustration we will take the working of a small spiegeleisen furnace in Eastern Pennsylvania, which, as far as fuel consumption and general efficiency is concerned, will represent fairly well the conditions of our case, and may be taken as typical of the features of the small furnace of fifty years ago.

CONDITIONS.

Composition of gas by volume :	
CO_2	3
CO	33
H	2
N	62
Spiegel produced	6,818 kilos daily.
Fuel used	29,000 " "
Flux used	19,500 " "
Carbon in spiegel	4 per cent.
" " fuel	85 " "
" " flux	11 " "
Efficiency of stoves	30 " " (iron pipe stoves).
Gas lost by leakage	10 " "
Pressure of blast	0·75 kilos per c.m². (11 pounds per inch).

RESULTS OF CALCULATIONS.

Calorific power of gas	1,052 calories per m³.
Volume of gas per day	137,204 m³.
Calorific effect " "	144,338,000 calories.
Required to heat blast, per day	50,000,000 "
Indicated horse-power of engine and pump	150

CONCLUSIONS.

Calorific effect of gases, per day		144,338,000 calories.
Lost (10 per cent.)	14,433,800	
For heating blast	50,000,000	
		64,434,000 "
Surplus for burning develops		79,900,000 "
Horse-power at 100 per cent. efficiency		5,200 horse-power.
Developable by steam at 3 per cent. efficiency		165 "
" " gas engines at 30 per cent. efficiency		1,650 "
Surplus power using steam		15 "
" " " gas engine		1,500 "

Remarks.—This little furnace barely raised enough steam power for its own needs. Using gas engines, there would have been a surplus of 1,500 horse-power, which is *at the rate of 22,000 horse-power per 100 tons of product per day.* This 1,500 horse-power would be sufficient to supply all the power needed in the works to which the furnace is attached, and save at least $50 worth of coal per day. It is to be understood that this furnace is an extreme case, and is cited simply to illustrate the general correctness of the conclusions of Case III.

CASE I (*b*).—We will present an example of very good modern practice, with exceptionally low fuel consumption (leaving the average case to the last, because of its greater relative importance).

The data are from a paper by J. Whiting, in the *Transactions of the American Institute of Mining Engineers*, June, 1891, and concern a furnace of the Illinois Steel Company, in South Chicago. The gases were exceptionally poor, the ratio CO_2 to CO by volume being 2 to 3, and the fuel consumption only 750 kilos per ton of pig iron (or 1,680 pounds per long ton).

CONDITIONS.

Composition of gas by volume :	
CO_2	15·7
CO	23·5
H	1·2
N	59·6
Pig iron produced daily	130 tons.
Fuel used per 100 kilos of pig iron	75 kilos.
Carbon in fuel, 100 kilos of pig iron	64 "
Carbon in 100 kilos of pig iron	3·75 "
Efficiency of stoves	70 per cent.
Efficiency of boilers and engines	5 "
Volume of blast per minute	247 m^3.
Pressure of blast	0·75 atmosphere.
Temperature of blast	850° C.

CALCULATIONS.

Calorific power of gas per m^3	743
Volume of gas per 100 kilos of pig iron	332·5 m^3.
Calorific power of gas per 100 kilos of pig iron	247,000 calories.
Required to heat blast, per 100 kilos of pig iron	125,854 "
Indicated horse-power of engines per 100 kilos of pig iron	220 horse-power.

CONCLUSIONS.

Calorific effect of gases per 100 kilos of pig iron	247,000	calories.
Lost (10 per cent.)	24,700	
Heating blast	97,070	
	131,770	"
Surplus for burning can develop	115,230	"
Surplus develops per 100 tons iron per day	115,230,000	"
Horse-power, at 100 per cent. efficiency	7,530	horse-power.
Horse-power by steam at 5 per cent. efficiency	375	"
Surplus power per 100 tons output daily	155	"
Developable by gas engines at 30 per cent. efficiency,	2,260	"
Surplus power per 100 tons output daily	2,040	"

Remarks.—This result is 100 horse-power less than the minimum before calculated, but a large allowance of 10 per cent. has been made here for loss, and a reduction of 1 per cent. in this item would increase the surplus power 160 horse-power. The great loss of gas occurring during charging and by leakage is an item which is being rapidly reduced by economical managers.

CASE II.—To illustrate this case, that of average blast furnace practice, we will take the data from a blast furnace plant in Eastern Pennsylvania, which is making in three furnaces 2,600 tons of pig iron a week.

CONDITIONS.

Composition of gas by volume:	
CO_2	9
CO	27
H	1·8
N	62·8
Pig iron produced daily	370 tons.
Fuel used per 100 kilos of pig iron	100·0 kilos.
Carbon in fuel, 100 " " " "	82·9 "
" " flux, 100 " " " "	4·6 "
" " 100 " " " "	3·1 "
Efficiency of stoves	60 per cent.
" " boilers and engines	4·5 " "
Pressure of blast	1·3 kilos per cm^2 (20 pounds per square inch).
Temperature of blast	555° C.

CALCULATIONS.

Calorific power of gas per m^3	873 calories.
Volume of gas per 100 kilos of pig iron	434·7 m^3.

Calorific effect of gas per 100 kilos of iron	379,490	calories.
Required to heat blast, per 100 kilos of iron	90,500	"
Indicated horse-power of engines for blast	950	horse-power.
" " " " " hoist, pumps, etc. (per 100 tons of iron daily)	65	"

CONCLUSIONS.

Calorific effect of gases per 100 kilos of pig iron,	379,490	
Lost (10 per cent.)	37,950	
For heating blast	90,500	
	128,450	calories.
Surplus for burning develops	251,000	"
Surplus per 100 tons of pig iron daily	251,000,000	"
Horse-power, at 100 per cent. efficiency	16,400	horse-power.
Horse-power with steam, at 4½ per cent. efficiency	738	"
Deficit of steam power, per 100 tons iron daily	**277**	"
Horse-power with gas engines, at 30 per cent. efficiency	4,920	"
Surplus power with gas engines (per 100 tons daily)	**3,900**	"
Deficit of steam power per 370 tons daily	**1,025**	"
Surplus of gas engine power per 370 tons daily	**14,400**	"

Remarks.—It is an actual fact that, at the works in question, the three blast furnaces are *charged* with 800 horse-power, furnished to them by the boiler plants fired by coal. It is also a fact that nearly 10,000 horse-power is raised for the rest of the plant by coal-fired boilers, and that *all of this* could be supplied by gas engines utilizing the blast furnace gases. The saving in the coal bill alone would amount to at least $150,000 in one year. The gas engine plant to accomplish this would cost $500,000.

Conclusion.—I have chosen to conclude with this case in order to leave an adequate impression of the great industrial revolution which is imminent in the economical utilization of blast furnace gases.

METALLURGICAL DEPARTMENT, LEHIGH UNIVERSITY,
November 2, 1900.

Mechanical and Engineering Section.

Stated Meeting, held May 10, 1900.

EXPANDED METAL

AND SOME OF THE USES TO WHICH IT IS PUT.

By James S. Merritt, M.E.

"Expanded metal" is an excellent illustration of an article which has been found to be applicable to far greater extent and for purposes not thought of in the beginning by the inventor, than to those which he had in mind when he first conceived the idea. When Mr. John F. Golding, of Chicago, first attempted to make expanded metal he expected to use it as a material for fences, window guards, etc., and he called it "slashed metallic screening." It is probable that less than 1 per cent. of the output of expanded metal at the present day is used for these purposes, the greater part of it being used now in the fireproof construction of buildings. This development is largely due, however, to Mr. Golding's efforts, and there are at the present time four companies in the United States and five or six in Europe manufacturing expanded metal. There are also a number of local companies engaged in the fireproofing of buildings, and $10,000,000 is probably a conservative estimate of the capital now invested in the expanded metal business in its various forms.

The Franklin Institute was the first scientific society to recognize the merits of expanded metal by awarding, in the year 1892, the John Scott Medal to Mr. Golding for his invention of expanded metal, and this action has since been justified in a remarkable degree. It would be difficult to find any other name for the material which would so well describe it, and the French "metal deployé" and the German "Streckmetall" both follow the American idiom.

Expanded metal is cut from a sheet of open-hearth steel, expanded, or opened into a netting of any desired size of

mesh or section of strand. The operations of shearing the steel and opening the meshes are simultaneous, and are performed cold. No material is wasted, as there are no pieces cut out. The finished sheets are from three to eight times as large as the original sheets of steel, according to the size of the meshes and the width of the strands.

The grades of expanded metal which are in commercial use to-day vary from ⅜-inch mesh, cut from No. 27 B. W. G. steel, to a diamond mesh 5 x 12 inches, cut from No. 4 gauge steel. The sheets are usually 8 feet in length, and the machines which do the cutting have to be slightly more than this in the clear between the housings. They are very heavily and substantially built, as it is necessary that they run with smoothness and accuracy, for the shear blades have to be adjusted with great care to make a clean cut. I show you on the screen the front of one of the machines in the works of the Central Expanded Metal Company, near Pittsburgh. The shaft of this machine is 8 inches in diameter, although it is reinforced at two points in 9 feet by bearings upon the lower side of the heavy lintel which extends across from housing to housing. This will give an idea of the substantial construction which is necessary in order that these machines may do good work. The plate of steel to be cut is placed upon the table on which the workman is resting his left hand, and is then fed in by degrees under a clamping device which holds the sheet down solidly against the bed while the cutting is being done. The original method of cutting expanded metal did not involve any stretching of fibers of the steel. The sheet was fed through the machine in a diagonal direction. The first stroke of the shear blades cut one mesh and pushed it down at right angles to the plane of the sheet of steel. The second stroke of the blades produced, in a similar manner, the next three meshes, while the third stroke produced five meshes. The distance between the housings of the machine limited not only the length of the sheet, but also the breadth, and most of the old machines were unable to produce a sheet more than 8 feet in length by 4 feet in breadth. The sheets of expanded metal were never quite

square, and the thickness of the steel which could be worked in this way was limited. Before placing the sheets of steel in the machine it was necessary to cut them to the exact size to give the desired sheets of expanded metal.

In 1894 Mr. Golding invented and patented another method of cutting expanded metal, and this has proved far superior to his former invention, and of wider range. The sheets of steel are now fed through the machine in the direction of its shorter axis instead of diagonally, as in the old method. The shear blades, instead of being each set diagonally and in a different plane, now consist of a stationary straight lower blade and a series of diamond-shaped blades in one vertical plane carried by the movable upper head of the machine. The distance between the points of adjacent blades determines the length of the greater axis of the meshes, while the shape of the blades and the stroke of the machine determine the width of the meshes. In changing the machine from one mesh to another, it is not necessary to change the lower blade, but merely to change the upper blades.

We will suppose that it is desired to cut 3 x 6 inches mesh expanded metal from a sheet of No. 10 steel. Expanded metal above No. 14 gauge is usually cut with an approximately square strand, or in other words, the width of the strand is about equal to the gauge of the steel. The sheet of steel is placed in the machine with its edge projecting at the back $\frac{1}{8}$ inch beyond the lower shear blade. The machine is started, and the movable head which carries the set of diamond-shaped shear blades comes down upon the sheet. The points of the row of upper blades, some sixteen in number, strike the top of the sheet of steel, and begin to shear it away from the rest of the plate, and at the same time to push downward in a vertical direction the strand so formed. The steel must be of the proper quality, as the elongation amounts to over 10 per cent., the corresponding reduction being greater in the thickness than in the width of the strand in about the ratio of 1·16 to 1·00. The upper knives are stopped in their downward movement just before they have travelled far enough to

completely sever the strand from the original sheet. The strand is left connected with the sheet by a strip of solid steel, which is technically known as "the bridge." The head is then raised and the plate is shifted laterally a distance equal to one-half the long axis of the mesh which is being cut. It is then fed the width of one strand beyond the edge of the lower plate, and the machine is ready for a second stroke. When the head descends, the points of the upper blades strike upon the bridge, and begin the shearing process at that point. The manner in which the sheet of expanded metal grows in size is shown in the illustration.

After a sufficient number of strokes to form a sheet of expanded metal of the desired width, the feed of the sheet of steel in a horizontal direction is intermitted during one stroke of the head. The upper blades cut through the "bridge" on the same line as the shearing done during the preceding stroke, and as a result the expanded metal is entirely separated from the solid sheet of stock.

When expanded metal is made by this improved process the sheets are exactly square, and the width of the sheet is only limited by the width of the original sheet of steel, or by the possibility of removing the sheets of expanded metal, which issue vertically downward from the back of the machine. It has been customary to build a pit behind the machine to get the necessary room, and it is not possible, at the present time, to turn out sheets of more than about 8 feet in width by 9 feet in length, the latter dimension being limited by the distance between the housings of the machine. It is evident that it would be possible, should occasion demand, to cut a 48-inch wide sheet of No. 10 steel into a single sheet of 3-inch mesh expanded metal about 32 feet in width.

Steel is the material generally employed, but it is equally possible to expand brass, aluminum, or other metals, and considerable of this has been done to meet special requirements. The sheets of steel have to be annealed, pickled and treated in various ways during the process of conversion into expanded metal, but these processes are not inter-

esting in character, and we shall, therefore, not go into them in detail.

It has been argued that the process of cutting must cause incipient cracks in the steel, which would greatly reduce its tensile strength, and an elaborate series of tests was made in 1897 at the Massachusetts Institute of Technology which showed conclusively that such is not the case. The test pieces were considerably reduced in area at the point of rupture, and the appearance of the fracture was normal. The uniformly satisfactory condition of the steel in expanded metal is, in great part, due to care in the selection and preparation of the stock, and the fact that the shear blades are kept in much better condition and more accurately adjusted than is usually the case with shearing machines.

It has been already stated that expanded metal is described commercially by giving the width or short axis of the diamond mesh and the Birmingham gauge of the original sheet of steel.

To describe the material exactly there should also be stated:

(1) The angle formed by the long axis of the meshes and the strands of the expanded metal (usually about $12\frac{1}{2}°$), which is determined by the shape of the upper shear blades; and,

(2) The width of the strands (measured at right angles to the original thickness of the plate), which depends upon the "feed" of the machine, which can be varied within certain limits. The feed is usually about one-tenth greater than the thickness of the plate.

The weight of expanded metal proportioned as above can be found from the equation:

$$W = 100\ \frac{t^2}{m} \qquad (1)$$

in which W is pounds per square foot.

t thickness in inches corresponding to the gauge number.

m length in inches of the meshes.

The constant 100 depends upon the angle of the meshes and the width of the strands.

We will now consider some of the practical applications of expanded metal, which may be divided into the following groups:

(1) Fireproofing of buildings.
(2) Concrete structures.
(3) Exterior of buildings.
(4) Miscellaneous.

(1) *Fireproofing of Buildings.*—The principal use of expanded metal at the present day is for the fireproof construction of buildings and as a "binder" in concrete structures of all kinds. The extent of this use is shown by the fact that over 9,000,000 square feet, or 200 acres, of various grades of expanded metal were used in the buildings of the Paris Exposition. This is greater than the area bounded by the Delaware and Schuylkill Rivers, Market and Sansom Streets.

In the United States there is scarcely a prominent building that has been completed during the last ten years in which there is not more or less expanded metal. It was first used in building construction as a substitute for wood lath; it was secured by staples to each side of wood studs, and was found to give a much better support for plaster than had ever been obtained by the use of wood lath. This form of construction will resist the action of fire for a considerable time, but the next step was to do away with the wood studs by the substitution of some form of light steel bars, or rods.

By properly forming these supporting members any desired architectural effects can be had and at comparatively slight expense. The groined and panelled ceilings in the Library of Congress, Washington; Carnegie Library, Pittsburgh; Free Library, Boston; City Hall, Philadelphia; and the new Masonic Temple, Boston, are a few examples of this form of expanded metal construction.

In this system there is nothing to shrink or warp, so that there can be no cracking of the finished surface, and the

perfect "key" of the plaster on the expanded metal lath is a guarantee that the plaster will never fall off and that the most elaborate decorations may be applied with entire confidence.

About eight years ago it occurred to Mr. Golding that a partition could be built in which but one surface of lath would be used instead of two, as had been the custom, and the result was a "solid partition" 1½ or 2 inches thick. The writer is free to confess that he did not believe these partitions would do more than support their own weight, until he had actually seen them in place. Light steel studs, usually of ¾ x ⅝-inch channel section, are set up at distances of about 16 inches, and expanded metal lath is then secured by wire ties on one side of the studs. The lath is plastered from the front, and when the mortar has "set" another coat of plaster is placed upon the rough "keys" which form the back of the first coat. One or two more coats of plaster are added to each side of the partition, which can be given any desired finish. These partitions are not intended to carry any load, but are merely for the purpose of dividing rooms. They are proof against sound to a remarkable degree, and the most reasonable explanation of this property which has yet been offered is that the sound vibrations, entering one side of these partitions, are intercepted by the network of steel and carried off laterally to other parts of the structure and so dissipated, instead of being allowed to pass directly through the partition. They also resist fire wonderfully well, as shown at the Home Life Insurance Company Building, New York City, and the Merion Cricket Club fires a few years ago.

About the year 1892 Mr. Golding made the experiment of embedding expanded metal in a concrete plate for flooring, and this invention has rapidly found its way into favor, the floors of some of the largest buildings in the United States having been constructed upon this system. It is really a modification of the Monier system, which was introduced in Europe in 1878, and by the use of which remarkable results have been attained in France and Germany. The principle involved is to place a sufficient amount of steel

wherever the structure is likely to be subject to tensile stresses, and to depend upon the concrete in compression only. The combination of steel and concrete in this way is an ideal one, as very light steel members can be used in most cases, and these are held firmly in place and protected by the concrete from corrosion, the steel in turn reinforcing the concrete against rupture under tension.

By reason of its peculiar construction a sheet of expanded metal laid upon a flat surface will touch the latter at a few points only, and as a result of this property it is not necessary to offset a sheet of expanded metal before applying the concrete. On account of the ease with which the sheets can be handled, and its greater power of "binding" the concrete, expanded metal is considered far superior to the straight Monier rods, which have to be laced together at the site.

In the construction of expanded metal floors, cinder concrete is generally used for two reasons; first, on account of its lightness; and second, on account of its excellent fire-resisting qualities. Cinder concrete has withstood, undamaged, many severe fires, both in practice and in test. The reason of this is apparent when we consider that Portland cement is burned at a temperature of over 4,000° Fahrenheit, while the temperature of the furnaces from which anthracite boiler cinders are obtained is even higher.

The roof of the new Mint Building in this city will be of expanded metal and cinder concrete, for the various departments of the United States Government have been prompt to appreciate the advantages of this system. It is possible to drive nails into the cinder concrete, so that slate or tiles can be secured directly to the concrete without the use of wood, which is always liable to decay.

(2) *Concrete Structures.*—Expanded metal has come into favor with civil engineers as a "binder" for concrete foundations, walls, etc., and has been largely used by the Engineer Corps of the Army in fortifications and gun mounts.

It has also been used, embedded in concrete plates carried by steel beams, to form the decks of bridges, and in concrete arch bridges. The principle involved in all these con-

structions is the same as in the case of floors in buildings, *i. e.*, to supply steel, in sufficient amount and the proper places, to resist all tensile stresses. A bridge 134 x 60 feet, which has just been built by the Erie Railroad over its tracks through East Newark, N. J., is an excellent example of the first type, while a number of county highway bridges have been built near Pittsburgh which illustrate both types. In the construction of a bridge at Sea Girt a considerable amount of money was saved recently by the substitution of vertical concrete plates, with embedded expanded metal, in place of masonry wing walls and abutments.

Expanded metal has been used to a considerable extent in the construction of concrete sewers. Several years ago, in the case of a sewer in the Neponset Valley, near Boston, it was impossible without going above the grade line to secure sufficient filling on top of the sewer to prevent its bursting upward under the pressure of water from within. The Metropolitan Sewage Commission finally adopted a construction in which a sheet of expanded metal embedded in concrete was used to tie down the upper part of the sewer, which was of oval shape. This plan was entirely successful, and the engineer of the Boston sewers later on overcame a similar difficulty by the same method.

Expanded metal has been used in the new sewer system of Worcester, Mass., and an illustration of it appears in the report of the engineer, which has just been published. In this city the Bell Telephone Company used expanded metal last winter in a sewer adjoining their large manhole at the Northeast corner of Seventeenth and Filbert Streets. It was desired to have the side of the sewer as thin as possible so that it would not occupy valuable space, but the west wall of the manhole rested directly upon the top of the sewer, and was liable to great loads from the street above.

(3) *Exteriors of Buildings.*—From the use of expanded metal lath for interior partitions, etc., it was natural to pass to exterior construction. A large house was built in Pittsburgh in 1892, the outer walls of which consisted of a wood frame covered with expanded metal lath, plastered with

Portland cement mortar. This proved such an unqualified success that many buildings all over the United States have since been built on the same principle. Old dilapidated brick or frame buildings can be veneered and made to look like new structures.

A recent instance of such a transformation is the Pennsylvania Railroad Station at New Brunswick, N. J., which was partly frame and partly brick which had been painted so many times that it would have been impossible to secure the adhesion of plaster. This station now presents a most attractive appearance. It is pebble-dashed all over so that neither brick nor weatherboards are visible, and no one would recognize the dilapidated structure of a year ago.

The surface of such buildings can be finished in many different ways. They can be trowelled smooth in Portland cement and sand, or can be pebble-dashed. A more elaborate treatment will yield the effect of quarry-faced or ashler masonry, which can be given any tint to harmonize with the surroundings.

In the construction of new buildings in which a greater degree of "fire resistance" is required, or which, to use the popular term, are to be "fireproof," the expanded metal in the exterior walls is carried on steel studs. The large buildings of the Walker Bros. Soap Works, at Pittsburgh, have been subjected to raging fires both from within and without at different times, without injury. The construction can be either of the "solid" type or double, with an air space, where it is important that very little heat pass through the walls.

(4) *Miscellaneous Uses.*—In addition to thousands of miles of fencing, a list of the many curious ways in which expanded metal is employed would include riffles for placer gold mining, bird cages, door mats, clothes lockers in manufacturing establishments, tree guards and brake shoes.

The "Diamond S" brake shoe is made of cast iron, but before the molten metal is poured a bundle of expanded metal lath, cut to approximately the size of the brake shoe, is placed in the cavity in the sand, which is then filled in the usual manner. The makers of this shoe claim for it not only

increased ability to hold the wheel, but also much greater life for the brake shoe without greater wear of the wheel.

In conclusion, there seems to be no limit to the uses to which this material can be put, and it is another example of that ingenuity which bids fair to gain for the United States the commercial supremacy of the world.

THE SIGNIFICANCE OF CRYSTALLINE FORM.*

By W. F. C. Morsell.

Matter.—The endeavors to define matter at the present day are too many to count; but as they are confessed failures, the outcome is a forcible reminder that the real nature of matter is insoluble. We must be content to know that matter exists with tangible properties and uses. The existence of matter in the state of a subtle, undivided substance, extending throughout finite space and serving as a medium for the modes of motion manifested in energy, is axiomatic, self-evident and conclusive to scientific minds. This extended substance is the ether, supposed to be a continuous, ungranulated state of matter, out of which the various chemical elements have been developed by the action of force.

In contact with gross matter the sense of touch gives us a perception of mass as composed of particles, granulated with fine or coarse grains. Such matter becomes less appreciable to the senses as the particles or grains are more and more separated in space; but the various stages of separation are marked by recognizable properties and are known as states of matter, such as solid, liquid, vapor and gaseous.

Theory of Gross Matter.—A theory of gross matter in solid form is approachable by assuming a generalized, geometrical figure, such as the sphere, to represent a unit of mass. According to such a hypothesis, an elementary

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chemical substance should be conceived as a group of spheres of uniform size and of a mass specific to that element. The liquid state can be represented in rolling contact and unstable equilibrium; the solid state, by spheres also in contact but in stable equilibrium.

Having selected a suitable material (steel), let a sphere of unit volume stand for a particle of hydrogen; then the other elements may be represented by steel spheres whose cubic contents correspond with the atomic weights or volumes. This hypothesis of spherical units supplies stereo-chemistry with sets of units which can be arranged according to chemical formulas in such crystalline envelopes as belong to the formulas in nature. The units in such an envelope should be arranged in the order of their melting points, the highest melting point giving the core of the figure. This method of investigating form and structure by the close packing of spheres may be extended to vegetable and animal morphology and histology, since protoplasm differentiates into cells with spherical envelopes and these cells are assembled and arranged, during the process of growth, into configurations depending on the resolution and composition of the forces at work. This program reduces all the phenomena of nature to the sway of the laws of motion.

Inertia.—A normal experience of the sense of touch shows gross matter to be destitute of self-moving force and with a tendency to seek stable equilibrium in a zero of motion, which is known as rest, or repose. This is the primary sense of the adjective "inert"—destitute of power to move itself. It is a property of matter, depending on mass, that it resists change of position when at rest; and when in motion it resists change of direction and also requires a countervailing force to bring it again to rest. All calculations of energy consider rest as the zero of motion. Combining these notions, we arrive at the property of matter called "inertia," the persistence of mass in any state imposed upon it by force. Matter, apart from force, thus remains in repose until the conquest of inertia by force.

Force the Cause of Energy.—"Energy," in its modern use, has been confounded with "Force." Energy is best described as a mode of motion, *e. g.*, heat, light and electricity are modes of motion differing only in wave length. It is self-evident that such modes of motion in a substance destitute of self-moving force can be set up only by the entrance of a cause sufficient to overcome the inertia of the mass with which the cause is dealing. To dispense with such an initial conquest of inertia involves the necessity of stripping matter of its most distinctive property; however, if we revive Sir Isaac Newton's definition of force, "that which produces motion or tends to produce it," we can then make a rational statement as to the origin of modes of motion. *Force is the cause of energy.* This force, by definition, has no inertia, and, being devoid of the most distinctive property of matter as well as having the ability to overcome inertia, must be regarded as *immaterial.*

Specific Stability.—Matter passing from a liquid to a solid state seeks a position of stable equilibrium, and, if the solidification takes place on a horizontal plane, a second plane is formed by accommodation as part of the surface of the new form. In proportion to the area of this new plane there will be a stability with its center in a line normal to the plane surface. When a chemical element solidifies under conditions favorable to crystallization it acquires an envelope of plane surfaces, and, if left free to seek a position of rest, it will show a center of stability in a line perpendicular to its largest plane face. This is a specific stability peculiar to every substance to which nature has assigned a specific geometrical envelope. The idea of a specific envelope in geometry is known to be a relation between a mass and its bounding surface; the cube has a surface larger relatively to the enclosed mass than any other figure; the sphere has the smallest surface relative to its contents. As in a series of geometrical figures the number of plane faces increases, the faces diminish in area and the total envelope decreases in superficial area until the least surface is reached in the sphere. In such a series the stability varies inversely as the number of the faces, and directly as the area of the largest face.

To make the matter plainer, let us consider three crystals: a cube, an octahedron and a quartzoid, or twin hexagonal pyramid. The square face of the cube evidently has a larger area than the triangular face of the octahedron, and the isosceles triangle of the hexagonal pyramid is again less than the equilateral area of the octahedron's face. If these figures rest on a horizontal plane a greater amount of force is required to tilt the cube than to tilt the octahedron, and, again, the octahedron resists overturn more vigorously than the quartzoid. This specific stability is modified by the specific density of substances and the resistance to overturn will equal the product of the area of the largest crystalline face and the specific gravity of the material.

Form and Internal Structure.—Crystals grow by the deposition of planes. These planes of growth become planes of cleavage, *i. e.*, of least cohesion to such an extent that some crystals separate into laminæ of thicknesses bearing appreciable relations to wave-lengths of light. So minute are the thicknesses that laminæ of mica may be used to differentiate shades and tints of color in polarized light.

To illustrate the effect of the laminæ, recall the laminated wood used in making models of ships. Alternate layers, dark and light, are glued together, and when cut finely, present the ship-curves intersecting the planes of dark and light material. Suppose a loosely made model with the layers slightly separated instead of closely glued. Let the separation be sufficient to allow the water to move between the planes with the wash of the waves. Such a ship model, if it met a system of waves, must present planes of least resistance to which any transmitted waves would be accommodated by the compounding momentum of the water meeting the resistance of the planes of the model; the transmitted waves will then issue, following the lines and planes of least resistance imparted to them in their passage, and these vibrations reduced to one plane constitute plane polarized light.

When any system of waves, heat, light or electricity enter a crystal, the vibrations are accommodated to the planes of least cohesion. The effect of lines of least and

greatest resistance at a right angle to each other is to divide a transmitted system of waves into two beams with their vibrations at a right angle to each other, and that beam which met the greater resistance shows the retardation by its deviation from the original path of the ray, this division of the ray being characteristic of double-refracting crystals in which the axes are unequal. The figure of such crystals is elongated in one direction and shortened in another at a right angle, and the faces of such a crystal are usually diamond-shaped.

A flexible square (see *Figs. 15* and *16*, Plate I), corded with string so as to divide it into smaller squares, when deformed by stress into a diamond, separates the strings in one direction and crowds them together in a plane at a right angle with the direction of their separation. Such a model represents one of the laminæ of a doubly-refracting crystal, and the pairs of acute and obtuse angles at the corners denote a strained condition of the interior arrangement of the particles in that face; now, as the whole crystal is built up of recurring laminæ, the structure of which is similar, therefore the internal arrangement of particles must correspond in parallel planes to the structure indicated by the external faces, and, in diagonal planes, the structure must be the resultant of the intersecting planes; so that the form of the crystal is a true projection, in three dimensions, of the internal structure.

Form and Stable Equilibrium.—The conditions of stable equilibrium for spheres in contact with planes composing the envelope of a cube may be studied experimentally in cubic shells made of thin sheets of cork and mica. The first three figures (*Figs. 1, 2, 3*) in Plate I show the three arrangements which can be made inside of a cube with steel spheres. *Fig. 1* shows the closest packing; it contains fourteen balls with the balls in contact on the diagonals of the face. This diagonal line represents the edge of a regular tetrahedron as a rational edge measured by the whole number, three. The middle ball is the apex of an octahedron composed of six balls. On the face of a large cube the square arrangement of the balls in contact would

show the squares set diamond-wise. The squares with edge lines parallel with the cubic edges show the balls not in contact. This position of the squares with open or closed edges is vital in relation to the number of spheres which can be contained within a cube of given size.

Fig. 2 shows the arrangement of the spheres in squares with rational edges parallel to the cubic faces—the arrangement in all three planes being alike. The structure of such a cube shows the largest possible interspaces, and the arrangement of the structure is homogeneous in every direction normal to the faces, but the balls are in maximum unstable equilibrium.

Fig. 3 gives a packing in which the rows of balls in alternate layers rest in the hollows of the adjacent rows. The packing is in stable equilibrium with the smallest possible interspaces, but it will be seen that the face has dissimilar corners and the solid angles at two opposite diagonal corners are truncated. The dimensions resulting from such packing are isometric normal to the faces and asymmetric along the diagonals joining pairs of solid angles measured through the cube.

In *Figs. 4* and *5*, Plate I, adjoining faces of the same figure have been shown. *Fig. 4* shows the closed square of balls with edges parallel to the cubic faces. The next layer shows nine balls, one in the hollow between every four of the face layer. This is stable equilibrium, but in *Fig. 5* the adjoining face shows a difference of arrangement and a loss of the cubic dimension between the vertical faces of the cube. This shows a closest packed arrangement which could never be isometric.

In *Figs. 6, 7, 8, 9* the series of shapes alter in a way to be appreciated only by considering the packing of spheres in relation to a sequence of figure ranging from minimum density and maximum volume to minimum volume and maximum density.

Form in Relation to Density.—An assemblage of small spheres may be used for a concrete geometrical investigation of the relative position of mass units referred to an envelope of plane surfaces such as constitutes a crystalline

figure. A set of bicycle balls of one size may serve the purpose, as these are exact spheres.

On a level surface, a piece of felt, arrange four balls in contact bounded by a square. The interspaces are the largest possible for contact, and the balls are in unstable equilibrium; but if the boundary be changed to a diamond, the new position gives the smallest possible interspaces and the balls are in stable equilibrium. One pair are in contact on the short diagonal, and on the long diagonal another pair are far apart; the lines of separation were at a right angle in the square, but are now oblique, and these are lines of greater and less resistance. One arrangement is more dense than the other.

If a solid figure be built up of a set of spheres of uniform size, the planes parallel to rectangular faces in a cubic figure hold balls in unstable equilibrium, and the interspaces will be the largest possible for spheres in contact; this is minimum density and maximum volume. Without walls this group will fall apart, but a practical model may be secured either by threading wooden balls on an elastic string, or, better, by making a hollow cube of cork and mica, with an edge measuring, say, three diameters on the interior, the shell thus obtained holding twenty-seven balls. See *Figs.* 6, 7, 8 and 9, Plate I.

Now, let us suppose a series of figures, hollow shells of the same inside edge, to hold additional sets of balls of the same size and number as the cube. Let the second figure have two diamond faces, the third four, and the fourth six diamond faces, the obtuse angles of all the faces being 120°. These hollow shells are now to be filled with the balls and then, on examination, it will be evident that the interspaces diminish in size and the density increases as the faces successively pass from squares to diamonds, until the last figure with six rhombic faces has maximum density and also a minimum volume, the surface having decreased in every succeeding figure.

An example of the law of inverse squares may be found by comparing the line functions of the solid angles of the last figure of the series with the similar functions of initial change in the second figure.

The final figure with none but rhombic faces, which exhibits maximum density from one point of view, is hexagonal when assigned a place among the classes of crystals; but this figure may be analyzed into isometric elements, an octahedron and two tetrahedra. It is probably more than a coincidence that the greatest specific gravities are to be found in crystals of isometric and hexagonal figures.

Form as the Result of the Composition and Resolution of Forces.—In nature, where the transitions of growth pass from the curves of soft, plastic material to the straight line boundaries of polygonal figures assembled in tissues, if the pressures are symmetrical the resultant lines are symmetrical. *Fig. 10* shows the collapse of a copper tube under pressure, forming a series of superposed equilateral triangles, and *Fig. 11* is the same tube shown in a cross-section with the hexagonal plan resulting from the superposition of the equilateral triangles. A number of closely packed spheres would collapse into geometrical solids with plane faces. In *Figs. 12, 13, 14* are shown the results of packing spheres in cylinders. Glass tubes are used. In *Fig. 12* the balls form a wave line the amplitude of which depends on the diameter of the tube and the length of the undulation on the size of the spheres. In *Fig. 13* the composition of two such wave lines is shown to be a double spiral. In *Fig. 14* the composition of several spirals is shown, forming a hollow tube like the stem of a vortex; the vortex may be experimentally shown by small spheres in a glass funnel. Two such funnels arranged end to end in dumb-bell fashion would represent the axis of a sphere in which the surface particles flow in at one end and out at the other end. In microscopic cell-life the amœba form floating in a liquid takes such a spherical shape with a flow along the axis in at one pole and out at the other; virtually this corresponds to the smoke ring conception of an atom, with a very small opening along the axis, in which the flow would be a vortex motion. Such an axis would give positive and negative poles to a spheroidal atom.

Form and Chemical Composition.—The numbers called "atomic" are now also recognized as "mass numbers" in chemical teaching.

Let it be assumed that the chemical elements have been derived from one substance, and that any element may be represented by a set of spheres, all of the same cubic con-

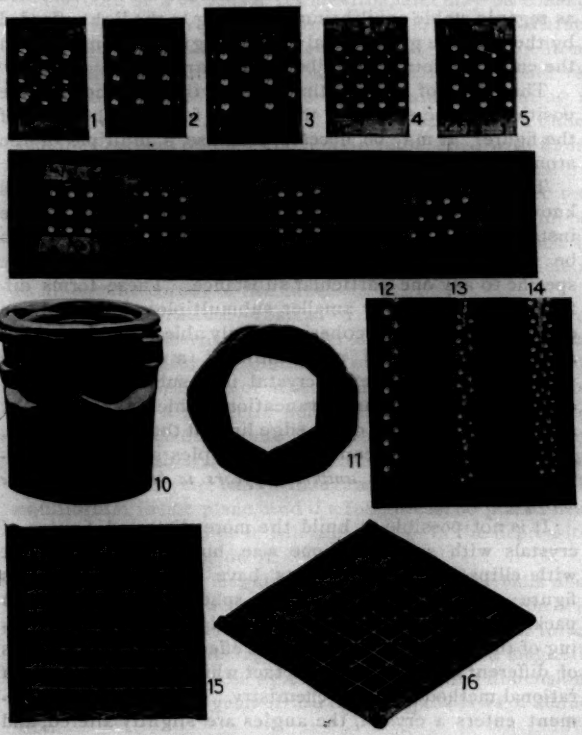

PLATE I.—The close packing of spheres, illustrating form and structure resulting from the composition of forces.

tents as the mass numbers assigned to that element as its atomic weight; then a stereo-chemical investigation is possible by using a hollow crystal model such as nature has

assigned to a known chemical formula. Two or more sets of balls, differing as the atomic weights, may be selected by the aid of the proper formula and fitted experimentally into the crystal envelope. The problem must first be attacked as regards stable equilibrium according to the light afforded by the concrete geometrical series of figures beginning with the cube, previously described in this article.

The order of the melting points will show the relative positions of the elements, the highest forming the core of the figure. It may be necessary to use a multiple of the atomic weight to solve the problem.

The elements usually assume isometric forms which it is known can be built out of spheres of uniform size. Those instances in which elements are not isometric crystals can be met by supposing the spheres to have an elasticity specific to any one particular substance. These forms differ by being larger or smaller submultiples of the volume of the cube as though cohesion is only able to hold together a specific number of mass units of a specified atomic weight. Every isometric crystal is a submultiple of the cube, by bevelments and truncations, which take place at submultiple segments of the edge lines of the cubic envelope. Nature thus gives geometrical multiples as well as multiples by weight. *The universe appears to be a vast concrete multiplication table.*

It is not possible to build the more distorted figures of crystals with spheres of one size, but they can be built with ellipsoids; so physicists have made a pet of this figure; and yet it suffices if the spheres be elastic; for in packing, such spheres may become ellipsoids: but the building of the distorted shapes may be effected by using spheres of different size, and it is this fact which gives a hope of a rational method in stereo-chemistry. Whenever a new element enters a crystal, the angles are slightly altered, and this is exactly what occurs when a different size of spheres is combined with the uniform set in an isometric figure.

Calcium Fluoride.—Although the isometric figures are mainly elemental, there are exceptions. Calcium fluoride, although a compound, forms a cube.

The formula calls for 2 parts by weight of fluorine and 1 part of calcium. The atomic weight of calcium is 40, and that of fluorine is 19.

The core of a cube is a tetrahedron, and may be considered as formed by the composition of four lines of attraction, acting normally to the four faces of the tetrahedron. Four units of calcium, impelled by such forces, would resolve into a position of stable equilibrium, representing a regular tetrahedron in its well-known position in a cube. The four corners of the cube remain to be filled with fluorine, which would be in a gaseous state at a temperature which would allow the calcium to become solid. Let the amount of fluorine ($19 \times 2 = 38$) for one unit of calcium be represented by thirty-eight small spheres, one of which is equal to the hydrogen unit. This quantity is just sufficient to fill out the corner of the cube.

Form and Attraction.—Instead of holding the spheres together by the external compulsion of an envelope of tangent planes, a beautiful demonstration of figure as the result of the stable equilibrium of a set of uniform spheres may be had by using a magnetic field, which can be formed by placing a flat sheet of some thin substance over the poles of a strong horseshoe magnet. On the plane surface thus obtained three bicycle balls will arrange themselves in stable equilibrium in one plane, and if a fourth ball be placed near and over the first three it will seek repose in the depression between the balls below it.

Now reverse the magnet, and if the group of balls does not overtax the power of the magnet, the tetrahedron will preserve its figure as the result of the composition of forces in the magnetic field. Any group of spheres in a magnetic field resolving its forces symmetrically in three dimensions must assemble in a geometrical figure by the laws of attraction.

If two or three sets of bicycle balls be used to an extent of weight within the sustaining power of the magnet, figures with truncated corners and bevelled edges can be formed similar to the faces on natural crystals.

Figs. 1 and *2* in Plate II are the illustrations of a possible

formation of calcium fluoride in a cubic crystal. *Fig. 1* shows the effect of attraction in holding four particles of calcium on the poles of a horseshoe magnet. The transparent cube shows the position of the four particles in a cube forming the regular tetrahedron as the core of the cube and leaving the four corners vacant. *Fig. 2* represents the amount of fluorine as a gas required to fill the vacant corner. The masses of lime and fluorine are calculated according to the atomic volumes, *i. e.*, the atomic weight divided by the density.

Fig. 3 shows a goniometer set at the measure of the acute angle of a face of Iceland spar (calcium carbonate) and in this angle it is experimentally demonstrated that the spheres representing calcium and carbon, calculated with a volume corresponding to the atomic weights as mass numbers, when arranged in stable equilibrium under attraction on the face of the poles of a magnet, exactly fill the angle of the crystal in the plane of the face.

Form and Cleavage.—When the Abbé Haüy accidentally dropped a tray of crystals the breakage revealed that the small fragments were forms resembling the larger masses to which they belonged before their separation. From that time it has been a recognized truth that a crystal has cleavage planes of least cohesion by means of which it may be broken into smaller figures which are repetitions of the larger form.

This figure is a definite shape specific for every substance, whether elementary or complex, depending on chemical affinity. Now it takes but one step in generalization to carry us to the unavoidable conclusion that this theory of cleavage provides for the existence of a plane geometrical figure, a crystal of infinitesimal size, as the simplest conception of a unit of mass or a molar unit, the existence of which may be assumed as unquestionable even though it be invisible to the eye.

To carry the analysis still further, a geometrical investigation can be made as to the relation of spheres packed in stable equilibrium and also as to the relation of sets of spheres to an envelope of plane faces such as form a geome-

trical shape. This investigation is capable of showing not only the relation of one set of spheres of uniform size to such an envelope of tangent planes, but can be used also to examine the more complex cases where two or three sets of

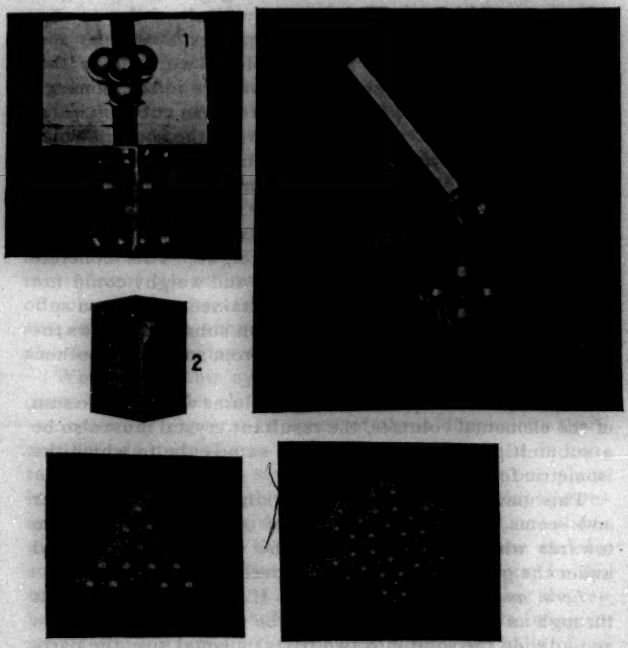

PLATE II.—Stereo-chemical models, with the spheres in multiple volumes representing atomic weights.

spheres of different size may be packed together as in the case of a chemical compound.

This relation of crystalline figure to cleavage and to a generalized spherical unit supplies education with a new set of models for teaching stereo-chemistry.

To resume what has been just said, the true chemical molar or molecular group, giving an envelope to the atoms, is an infinitesimal crystal as suggested by cleavage and the atoms may be conceived as small spheres assembled in stable equilibrium inside of a resulting geometrical figure the shape of which is the necessary result of the number and also of the relative size of the spheres.

Form and the Unity of Nature.—It is well known that nearly all the chemical elements crystallize in the isometric or cubic form. These forms differ from the cube by bevelments on the edge and truncations at the corners which occur at submultiple points on the cubic edge. The figure thus outlined is always an exact submultiple of the volume of a cube, but of what cube is not known. The truth of such submultiple geometric volumes corresponds to the well-known relation of multiples by weight. This concrete multiplication table in both volume and weight could not exist unless the crystalline forms contained a common substance, and the presence of a common substance shows the derivation of the chemical elements from some unit mother-substance underlying the universe.

As chemical compounds have a volume which is the sum of the elemental volumes, the resultant crystal must also be a submultiple or multiple of the same cube to which the isometric forms are related.

This view confirms the present kinetic theory of matter and seems to afford a valid proof of the unity of nature towards which the whole scientific world seems to tend under the guidance of recent discovery.

Form and Planes of Symmetry.—If a solid figure be cut through an edge line and along the diagonal of a face, so as to divide the solid into two parts of equal size, the parts will show two new faces made by the cut; both these fresh surfaces are the same in figure; they are called planes of symmetry. The two halves must weigh the same and may be alike in shape, but the shapes may also be unlike. If the half figures correspond both in shape and weight then the new dividing plane surfaces are figures representing a plane of symmetry both of figure and of volume in the original

solid. If the half figures be dissimilar in figure but alike in weight the dividing plane is said to be only a plane of symmetry of volume and not of symmetry of figure. Some crystals have no planes of symmetry of figure, but all crystals have planes of symmetry of volume.

Make a diagram of such a plane and examine the deviations from 90° by dropping perpendiculars on convenient lines, either vertical co-ordinate, a side or a bissectrix of an angle. Examine the lines to see if any intersecting points divide the lines into submultiple segments.

In the plane of symmetry of the regular tetrahedron the deviation from 90° is 19° 28′ 44″, and the sine is ·3333333 or $\frac{1}{3}$, which is the tangent of the angle 18° 26′ 4″, which belongs to the field of symmetry of another class of figures known in crystallography as orthorhombic. Angles which are not submultiples of the circle, but whose lines are submultiples of the radius, belong to the planes of symmetry of volume of geometrical solids, especially of crystalline shapes, but these submultiple segments of the radius may also belong to angles which are submultiples of the circle.

We may call this system of angles sequence angles because they connect classes of solid geometrical figures.

Sequence of Figure.—In space of three dimensions there are three degrees of freedom. Suppose nine balls in contact, surrounded by a square boundary, making one plane in a cube. To complete the cube, two more similar squares are needed; then these squares may be so placed, one above another, as to show the freedom in every plane and by successively shifting the squares two degrees may be destroyed, one degree by a shift to the right, another degree by a shift at a right angle to the first, the balls being in stable equilibrium in those planes where the balls of an upper square rest in the hollows between the rows of balls in the lower square. The third degree of freedom can only be destroyed by at last changing the square boundaries so that the hollows and crests of the rows coincide. The shift in all these changes is measured by a half diameter and irresistibly reminds one of the theory of half-wave interference in light. Stable equilibrium is reached by a series of

internal half-wave shifts which reduce the interspaces between the balls to the least possible size. Notice that, as the interspaces diminish, the series of figures pass from transparency to opaqueness. Here we have a sequence of figure related to density, stable equilibrium and permeability.

The cube, as the symbol of three-dimensioned space, has all of its faces normal to one another, and may be regarded as a graphic representation of free equilibrium in a fluid or liquid state from which crystals are formed.

Moreover, the axes of the cube are not only rectangular, but they are equal, so that they serve admirably to represent not only a primary class of crystals, but also their homogeneous structure; since if any figure has unequal axes, or the axes are inclined, in the plane of the extended axis or oblique axis there is a corresponding disturbance of the particles by strain or displacement. It is possible to analyze the cube into a series of figures with rational axes corresponding to the six types of crystals.

The axes of the sequence of crystalline figure are as follows:

Isometric	1	8 : 8 : 8
Tetragonal	2	2 : 2 : 8
Hexagonal	3	$\sqrt{5} : \sqrt{75}$
Orthorhombic	4	8 : 4 : 2
Monoclinic	5	8 : 5 : 2
Triclinic	6	8 : 5 : 3

In this scheme the monoclinic and triclinic are derived from the orthorhombic by a transposition of parts. These type figures are all exact submultiple volumes of the cube and conform to the law of multiple volumes by weight. In nature there is a sequence by which one class of figures may pass into another class of more heterogeneous structure. This sequence is accomplished by the dimorphisin of carbon, sulphur, selenium, carbonate of lime and the feldspar group. For example, the orthorhombic passes into monoclinic and the monoclinic into the triclinic class.

Form and Graphics.—By graphic design the composition and resolution of forces are represented by a diagram in

which both the direction of the forces and their relative magnitude correspond to the length and direction of the lines. These lines are limited to the plane of the diagram, but the outlines of a crystal, being in three-dimensioned space, have a greatly increased power of delineating complex action. It is known that in all crystal figures edge lines are harder than the faces; again, the apex of a solid angle is harder than an edge line. A concrete composition of forces takes place in these lines and points, and a skeleton model of any crystal is a configuration of its forces, a diagram of configuration in three-dimensioned space. The short lines between obtuse angles are measures of least resistance, and the longer lines between acute angles are measures of greatest resistance. A crystalline figure is nature's edition of the graphics of physical force.

Potential Energy.—Potential energy is the energy of a particle due to its position. This is taken advantage of in modern machine-tools in constructing cutting edges. The figure of a crystal in a state of revolution suggests similarity to a cutter. If the planes of a cube, meeting in a trihedral solid angle, are successively presented to an emery wheel with a narrow face, the wheel is dressed while it cuts, and the intersection of the resultant curves makes a drill-point unrivalled for boring, without splitting, a cross-section of wood. The particles in a crystalline figure have potential energy by natural assignment to the face, the edge line or the apex of a solid angle. All statements of the hardness of minerals are made in terms of the potential energy of a diamond point.

Form and Environment.—The nearest approach to crystallization without environment is the formation of a snow crystal in the upper atmosphere. Such crystals exhibit a freedom of development when not interfered with by limiting conditions, by accomplishing the lawful end of their organizing force, perfect symmetry. Every snow crystal is an approximately complete geometrical design of exquisite beauty.

When the same material crystallizes in contact with the windows and sidewalks, some examples retain the angles of

the hexagonal system in the inclination of the rays to a central stem; again, all straight lines vanish and fern-like curves take their place, so that the frost crystal presents a vegetative pattern.

> "The glory of the celestial is one, and the glory of the terrestrial is another."

The failure of symmetry is evidently due to environment. It appears to be an example of molecular coalescence without the agency of colloids. This molecular coalescence, that accommodation of crystalline material by which the crystal surrenders its normal figure to enter into the shells and bones of animals, has been induced by microscopists, the mere location of a salt in a colloid solution being sufficient to show the conformity of the crystallization to its environment. The susceptibility of the crystal to its environment continues through all the stages of its growth. There is a continuous action and reaction between the crystal and its surroundings, usually registered in zones.

The formation of a crystal is a dynamic development governed by mathematical law, realizing perfect symmetry in proportion to the non-interference of "natural selection," which is a negative influence and can never be recognized again as the chief factor in evolution. A program of "dynamic" development reaching to the limits of the physical universe underlies all environment and is winning a progressive triumph for the survival of the best.

It is strange that this system of dynamic development, dependent on the laws of motion and the composition of forces, has been missed by the acute investigators who have advocated the well-nigh exclusive influence of environment. They have done nobly with their partial truth, but the neglect of the data supplied by crystallization has deprived them of the fundamental law of nature, which strives after the realization of perfect symmetry and suffers its loss temporarily to serve, not hopelessly, but with patience and humility, under the yoke of accommodation to environment; "the ethics of the dust" manifestly seeking after perfection at the cost of sacrifice, which wise men, in all ages, know to be the true law of progress. It is well to close with a

definition of dynamic development, namely: The mode of the manifestation of force is a development in which form and structure are the results of the composition and resolution of the forces of growth, tending to produce perfect symmetry, and progress towards this symmetry is the measure of the subordination of environment to the laws of motion.

ADDENDA.

Form and Stable Equilibrium.—Much attention is being paid by English students to the problems of stable equilibrium represented by assembling spheres in the closest possible packing. It may or may not be the case that atoms are in contact, but the atoms are supposed to occupy an average position in relation to one another capable of representation by an assemblage of spheres at the centers of which the atoms may be situated and even in a kinetic equilibrium the phenomena may be experimentally investigated by the relations existing among a group of spheres with a geometrical envelope of plane faces enclosing them.

In a cubic envelope the balls may be packed in three different ways, which can be best understood by inspecting the models as represented in the illustrations which have been prepared from photographs.

In the *Fig. 4*, Plate I, the empty cubic space was packed with four balls in a row in the closest square order possible and the second plane of balls was packed in the hollows of the lower first row with the result that the adjoining faces present show a different distribution of the balls in planes at a right angle with the face that was first laid in position. This arrangement could not result in a cube, for in a cube the face with a four-square of balls does not allow the balls to be in contact, but gives an open square.

A good illustration of dilatancy by heating may be had by regarding the heat as acting first on the outer layer, which in the act of expansion could no longer have its balls fit exactly in the same hollows which they fitted exactly before the heating.

Note that if a difference of dimension occurs in such

packing the difference of one line from another is necessarily a half-diameter for the displacement that allows one row of balls to occupy the hollows of the next row beneath. This suggests a reason for the rational or multiple relation in the axes. Dimension measures must show a difference like the displacement of crystals.

Note.—Figs. 15 and *16*, Plate I. The model of an elastic square is used to illustrate the structure of a single lamina in a crystal. The lines parallel to the side are unelastic cords which undergo no alteration in length when the square is deformed under stress, the only alteration being in the shape of the area included between the lines. The effect of the stress is a strain in the direction of the long diameter of the resulting rhombus and the lines in this diagonal are made of elastic material. When the model is changed under stress there are two unequal elasticities present represented by the short and long diagonals at a right angle with each other.

Note.—Figs. 4 and *5*, Plate II. In the two models of the structure of a snow-crystal, the triangle represents the hexagonal element as the accepted formula suggests in which a molecule of water contains one oxygen atom with two atoms of hydrogen, the steel ball standing for oxygen weighing sixteen of the unit balls, one of which represents hydrogen. The hexagonal model has two balls for the oxygen, each ball weighing eight of the hydrogen balls. In this case the balls are exact geometrical multiples, as the smaller has a diameter just one-half the diameter of the larger, the sphere following the cubic ratio in which a cube of half the edge of another has one-eighth of its contents. The sphere which equals twice eight involves the celebrated problem of the duplication of the cube.

Mining and Metallurgical Section.

Stated Meeting, held Wednesday, October 10, 1900.

THE CHEMISTRY AND PHYSICS OF CAST IRON.

Being a continuation of the discussion of MR. KREUZPOINTNER'S paper entitled "RIDDLES WROUGHT IN IRON AND STEEL." See *Journal of the Franklin Institute*, May, 1900.

MR. KREUZPOINTNER:—The extended discussion of my paper, "Riddles Wrought in Iron and Steel," shows a very gratifying interest by the engineer in applied metallurgy. If the discussion has drifted to that coy and intricate subject—cast iron—I am not surprised, since cast iron is a metal presenting many riddles for solution by the investigator.

It must be a satisfaction to our foundrymen to see so much interest manifested in cast iron, of which it was predicted that it would soon give way to steel. However, from all appearances the iron founder will live to a good old age, and the increasing liveliness of discussions and investigations of the properties and qualities of his product should encourage the foundryman to renewed energy in the observation and study of the peculiarities of cast iron.

It is by no means an unalloyed joy to discuss so complicated an alloy as cast iron, and not being a practical foundryman, my remarks can only be fragmentary and tentative.

In the examination of the qualities of cast iron we do not have the advantage, as we have it in steel, of being able to trace the causes of good or bad qualities back to their origin along the line of results of work from the ingot, along the heating, hammering or rolling. Cast iron remains in its primary condition as it comes from the mould, and the founder's skill and judgment are the principal factors in determining the value of his product.

Hence the duty devolves upon the foundryman to join hands with the scientist in order to increase our knowledge and advance his interests.

For the purpose of investigating the nature of cast iron our knowledge of steel helps us but little.

Structural steel is so far removed from its primary condition of the cast ingot, and even in its primary condition differs in its nature from cast iron so considerably, that a comparison is quite out of question.

Cast iron is a heterogeneous mixture of a number of chemical elements without any modification of the conditions in which they exist, by mechanical treatment, as in steel.

In cast iron we are not justified in making one factor responsible for certain qualities.

For instance, if an iron is weak, it is not necessarily weak because of an excess of graphite.

To make the graphite alone responsible would be like jumping at conclusions. To say that too much combined carbon makes cast iron useless would be a denial of the every-day fact that cast iron with high percentages of car-

bon, a minimum of which may be combined or graphitic, will be of exceeding usefulness to the engineer for specified purposes with all degrees of combinations between maximum and minimum percentages.

The excellent and timely work of the American Foundrymen's Committee on Standardizing the Testing of Cast Iron, with such eminent foundrymen as West and Moldenke as guiding minds, has advanced far enough to show us in what direction we might proceed in the future in a systematic inquiry of those peculiarities in cast iron which are still riddles to us, waiting to be solved in our technical colleges and by the members of this section.

The form or forms which the chemical elements in cast iron seem to assume during the last stages of solidification of the iron seem to have more influence on its final quality than the total percentage of this or that element.

Jueptner von Johrnsdorf hints on the appearance of carbon in five or six different forms in iron, and chemists tell us that other elements may, and do, assume two different forms. Hence, as long as we do not know with at least approximate definiteness under what conditions these various forms of the carbon and other elements are produced and found in the every-day product of the foundry, and what relation these various forms assume to each other, and what influence they exert on the physical qualities of the resulting casting, it would seem as if it would require the earnest co-operation of the practical founder and scientist to find a way out of these difficulties.

Our knowledge of cast iron will remain fragmentary until the scientist can tell the foundryman with what mixture, molten and poured at such and such a temperature, the various elements are in their most favorable relation to one another, producing best results. And even if we should ever attain to such a desirable degree of knowledge, much of the success in a foundry will ever depend on the individual skill and good judgment of the founder.

It is probably due to the successive modification of the elements and consequent reaction upon each other which gives us a good casting when, by analogy, if we con-

sider each element present only in one form, we should expect a bad or inferior casting.

Let us look for a moment at a few of the results of the Foundrymen's Committee on Tests.

CAST A.—Ingot Mould Iron, soft Bessemer mixture. The total carbon is 3·87 per cent.; graphite, 3·44 per cent.; leaving only ·43 per cent. combined carbon. The 1-inch square test bar, green sand, had an average transverse strength of 2,015 pounds, with a deflection of ·127 inch. The 4-inch square test bar, green sand, gave a transverse strength of 90,000 pounds, with a deflection of ·091 inch.

CAST B.—Dynamo Frame Iron. Total carbon, 3·82 per cent.; graphite, 3·23 per cent., leaving ·59 per cent. combined carbon. The 1-inch square test bar, green sand, gave a transverse strength of 2,360 pounds, with ·120 inch deflection. The 4-inch square test bar, green sand, gave a transverse strength of over 100,000 pounds, with a deflection of ·055 inch at 100,000 pounds.

In both these cases we have an excess of graphitic carbon, and since graphite itself is of low strength, we might conclude, from a purely theoretical standpoint, that such iron is worthless. Yet it is considered good enough for dynamo frames.

If we go to the other extreme we have:

CAST D.—Chilled Roll Iron. Total carbon, 2·36 per cent., of which only ·06 is graphitic.

The 1-inch square test bar, green sand, gave a transverse strength of 2,810 pounds, with a deflection of ·270 inch, while the 4-inch square bar, green sand, gave a transverse strength of 174,460 pounds, with ·140 inch deflection.

CAST E.—Sand Roll Iron. Total carbon, 3·04 per cent., with no graphite. The 1-inch square test bar, green sand, gave a transverse strength of 3,070 pounds, with a deflection of ·218 inch. The 4-inch square bar, green sand, gave a transverse strength of 168,640 pounds, with a deflection of ·140 inch.

Here again, according to theory, we might expect such excessive hardness and brittleness as to make the iron practically useless. In all four cases the deflection shows

the important influence of size of casting on the final quality of the metal. May we not surmise that, in these very carefully planned and equally carefully executed casts, the carbon and all the other elements were distributed through the mass of the iron uniformly in such variously modified forms as to support, rather than weaken, one another, and thus, together, helped to produce satisfactory results? If we could extend our search in that direction we might be able to find a satisfactory explanation for at least some of the perplexities which vex the foundryman's life.

There is another important factor determining the quality of cast iron which deserves our closest attention and the consideration of the foundryman. This is the phenomenon of segregation, of a dissociation of the chemical elements from one another when the fluid iron leaves the cupola or furnace, running through all stages of cooling of the metal.

In steel the effects of this tendency of the elements to segregate are more or less modified by the subsequent heating and rolling of the ingot.

In castings these modifying influences and agencies do not come into play, and the effects of segregation remain in full force. Other things being equal, segregation is the result of an excess in the iron of one or another, or several, of the chemical elements, and of the temperature of melting and the rate of cooling.

Segregation will begin with the first cooling after the fluid metal has reached the highest degree of melting heat and will continue, for all we know, through all degrees of cooling to the last stage of solidification of the casting. If the three necessary conditions of segregation are combined under favorable circumstances, the result may be the formation of the characteristic pine-needle crystals of iron, but more generally its results are a difference in structure in different parts of a casting, if the casting was large enough, with a consequent difference of quality in different parts and internal strains.

As far back as 1830, Rudberg in Germany, and, in 1834,

Fournet in France, found that a fluid solution of two metals may separate into two distinct bodies, each with a different melting point. It has been observed that with certain metallic solutions the variations in the melting and cooling points of the different constituents may result in a true chemical combination of a portion of the fluid until the saturation point is reached.in that particular portion.

The rest of the constituents, being in excess of the necessary quantity to form a true chemical combination, will form a mechanical mixture. These two bodies, or portions, will then solidify into one mass, but each with a different melting point, rate of cooling and physical qualities.

According to Roberts-Austen and Jueptner von Johrnsdorf, the true chemical combination and point of saturation in iron is reached with 95·7 per cent. iron and 4·3 per cent. of carbon, with a melting point of 1,130° Celsius, while the melting point of pure iron is given by Osmond as 1,530° Celsius.

According to high authority,* a minimum of temperature controls the melting and solidification of a given proportion of a mixture of elements. If a liquid mixture containing a given proportion of elements is cooled at the minimum temperature, or freezing point, agreeable to each element, then all the parts of a mixture will solidify uniformly at that temperature and no segregation would take place.

If, however, the mixture is composed of proportions of elements not solidifying uniformly at a minimum temperature, then the surplus or excess of these elements will solidify at a temperature higher than the given minimum.

If, then, we have a mixture of varying proportions of elements which do not all solidify at one temperature, we may expect as a result a series of formations of groups of elements as we go down in the scale of temperatures from the highest degree of melting point to the point of complete solidification, and the last of these groups will determine the practical value of the product.

*See Lehman, "Molecular Physics," p. 740.

Thus we can readily perceive the almost endless complexity of conditions arising in a cooling mass of cast iron, especially if the mass be large and hot, with ample time for play among the elements to produce partial or complete absorption, saturation, equalization, segregation, exchange and interchange among the various elements, according to their affinity, the law of crystallization, degree of heat of melting and rate of cooling, until the last group of elements, the mother metal, or so-called eutectic, is formed and the mass is completely solidified in every part.

These considerations seem to lead to the conclusion that it is somewhat hazardous to attempt to squeeze the practical work of mixing, melting, casting and testing of cast iron into the straight-jacket of cast iron rules and formulas until we know more of the causes and conditions which produce these complex phenomena. Meanwhile, and probably for a good while to come, we will have to trust to the practical skill, experience and sound judgment of our colleague, the foundryman.

MR. A. E. OUTERBRIDGE:—Responding to the call of the President of the Section, I would say that I have little to add to my remarks made during the first discussion of Mr. Kreuzpointner's paper. It may be well, however, to revert, for a moment, to the queries propounded by Professor Howe and my replies thereto by way of further explanation.

Professor Howe has approached the subject of cast iron from the standpoint of an expert in steel; my experience, on the other hand, during the past twenty years, has been confined almost entirely to cast iron. Hence the wide divergence of our views regarding the value of carbon as a constituent of cast iron. Applying his knowledge that "steel reaches its greatest tenacity with about 1 per cent. of carbon" to the complex combination of iron, carbon, silicon, manganese, phosphorus and sulphur (not to mention traces of other elements) commonly classed as cast iron, the Professor propounds an interesting and novel proposition, viz.: "If we apply this to cast iron, then the metallic part reaches its greatest strength with 1 per cent. (of carbon), *i. e.*, all combined carbon in the cast iron as a whole in excess of 1

per cent. is a source of weakness. It is also a source of brittleness and hardness. All graphite causes weakness and probably brittleness. * * * In short, all carbon in excess of 1 per cent., whether combined or graphitic, weakens the metal."

In my reply I have taken an opposite view because I do not consider that steel and cast iron are comparable with each other, at least with respect to the part that carbon (whether combined or graphitic) plays in imparting strength or weakness to the metal. In the case of steel all of the carbon is combined with the iron, while in cast iron carbon may be all graphitic, as in the softest grades, all combined, as in "chilled" or white iron, or part graphitic and part combined, as in strong gray cast iron.

The physical properties of steel and cast iron are as distinct as though the two metals were composed of entirely different elements, like gold and silver; and while it may be true that there is no sharp line of demarcation between cast iron and steel, the two metals, as commonly known and used, are radically different both in the solid and in the fluid state. For example, we cannot forge or weld cast iron; so, also, we cannot produce two entirely different qualities in different parts of one steel casting, by varying the rate of cooling from the fluid state, as in the case of a chilled cast-iron car wheel, where the "tread" is white iron, hard as steel, and the "plate" is gray, soft and comparatively ductile.

It should be understood in my former statement, viz., "I believe that the strongest and most ductile cast iron is that which contains a maximum of carbon (about one-half combined and one-half graphitic) and a minimum of all other elements except iron," that I did not mean to imply that it is practicable to obtain such metal as this from any blast furnace. I was merely discussing an ideal condition.

In point of fact, cast iron containing a maximum of carbon has usually a very small amount of that element in the combined form; the metal is, of course, soft and ductile, and has, therefore, comparatively little strength.

There are some reasons for believing that when cast iron is in the molten state nearly all of the carbon is in combi-

nation with the iron, but, on solidifying, the carbon separates either partly or wholly into the graphitic form; the more slowly the metal cools, the more complete is this separation. Practical advantage may be taken of this knowledge to make castings of large dimensions having much greater strength and ductility than could otherwise be obtained. If a large casting having thick section be poured from iron which shows good tensile and transverse strength in a test bar of, say, ½ inch, 1 inch, or even 1½-inch section, the metal in the casting will be of very different quality from the test bars. The grain will be "open" and the metal will be weak.

If, however, the composition of the charge in the cupola be such that the small test bars are white or mottled and, of course, brittle (because nearly all of the carbon is captured in the combined form, owing to the quick cooling), the metal in the large casting will be strong, comparatively fine grained and perfectly gray, due to the separation of carbon during the prolonged process of cooling.

The skill of the metallurgist, with the co-operation of an intelligent foundry foreman, can in this way secure, day by day with reasonable certainty, the production of castings having the qualities of strength, ductility, rigidity, hardness, or softness, as may be required, not only without increasing the cost of the materials, but, in many instances, with considerable economy. The most expensive grades and brands of pig iron are not necessarily the best for all kinds of work.

I regard the temperature of pouring cast iron as a very important feature in obtaining good, strong castings. You may pour from one ladle two castings of the same size and form, one at the proper temperature, the other may be too hot or too dull. In either event you will have two castings of different qualities, although the chemical composition of the metal may be the same.

Apropos of this, I will briefly mention an interesting investigation made in 1879 by Dr. Dudley, chemist of the Pennsylvania Railroad Company, the facts relating to which I found recently in reviewing my note books for the year 1881.

Ten old car wheels were selected for investigation, five

of which had failed after running an average of 24,349 miles each; the other five wheels had an average record of 122,463 miles in service. Drillings were taken from the five good wheels and also from the five poor wheels and analyzed with the following results:

AVERAGE CHEMICAL COMPOSITION.

	Carbon.	Phosphorus.	Silicon.	Manganese.	Sulphur.
5 good wheels . .	3·242	0·403	0·776	0·391	0·083
5 poor wheels .	3·306	0·396	0·714	0·449	0·090

The difference in chemical composition is scarcely more than might be looked for in analyses made from drillings taken from different parts of one wheel, and seem to indicate that the great difference in wearing quality was due to causes other than variations in chemical composition of the metal in the good and bad wheels. The relative proportion of combined and graphitic carbon is not given in these reports, but I believe that in the gray iron plate of a car wheel nearly one-third of the carbon is in combination with the iron and two-thirds in the graphitic form.

There appears to be a "critical temperature" for pouring cast iron in order to secure the best results, and it is, therefore, desirable that some portable, inexpensive, and fairly accurate instrument should be devised for reading, at a glance, the temperature of molten iron. Some years ago, an optical pyrometer, made in France, was brought out for this purpose, but so far as I am informed it has not proved entirely satisfactory, and I should be glad to know whether any members present have had practical experience in the use of pyrometers for determining the temperature of molten metals in their daily work.

In conclusion, I may say that I consider Mr. Webster's "Note on a Proposed Scheme for the Study of the Physics of Cast Iron," published in 1895, so comprehensive that I am unable to add any important suggestions thereto.

MR. ASA W. WHITNEY:—As the breaking loads and deflections of the bars quoted by Mr. Kreuzpointner do not give a very good idea of the effects of composition and of rates of cooling (due to ratio of perimeter to area of cross-section $\frac{P}{A}$), I have reduced the figures to the more com-

parable ones of modulus of rupture and average modulus of elasticity.

Cast.	Bar.	Modulus of Rupture.		Modulus of Elasticity.	$\frac{P}{A}$
			For Exact Dimensions.		
A	1" square.	36,270	—	6,870,000	4
	4" "	25,312	—	1,655,000	1
B	1" "	42,475	—	8,510,000	4
	4" "	28,126	—	3,030,000	1
D	1" "	50,580	44,125	4,510,000	4
	4" "	49,065	49,065	2,070,000	1
E	1" "	55,250	51,567	6,050,000	4
	4" "	47,430	43,513	2,000,000	1

In *Trans. of Am. Inst. of Mining Engineers*, March, 1895, there is a report of some of my experience with the pyrometer referred to by Mr. Outerbridge. Continued use tires the eye, which must be treated as part of the instrument and protected from glare of iron and occasionally standardized.

I would protest against the considerable amount of expense and study wasted on average analyses in cases such as that quoted by Mr. Outerbridge.

Note the date when chemical work was not so freely applied to cast iron as now. It is not likely that Dr. Dudley would now, after twenty-one years' further experience, use average analyses in such an investigation, except possibly where it was known that the five wheels averaged were cast under similar conditions and from the same cupola tap of one heat. If the wheels or any other scrap or pig iron is to be broken and mixed for use as melting stock, an average analysis is, of course, entirely proper. But as an argument for the importance of the pouring temperature or the insufficiency of the complete analysis of castings such comparisons are as defective as the belief that a fixed proportion of the total carbon is graphitic in the plate of good standard car wheels. That depends upon the *sort* of good composition employed.

As indicating roughly how the significance of the chemistry of these various good and bad wheels is, as usual, almost obliterated by the averaging of each lot, a rough formula, which can be improved, gives, when applied to the averaged analyses quoted, figures in the ratio of 100 to 96 for the good and poor lots respectively. If applied to the identical composition of each wheel, greater variations, like the following, would probably appear. The analyses tested below by formula occur in a paper by an inspector of the C., B. & Q. R. R.,* and indicate that my formula is worth improving and that analyses are too individual to be averaged until reduced to other terms.

	Relative Figure.
Wheels that failed in thermal test	78·95 to 82·50
" " stood " "	83·34 " 89·18
" " failed under fifty blows Barr drop . .	82·75 " 90·79
" " stood " " " " . .	96·50 " 100·

Another formula compares chilling capacity fairly well. Chill was evidently deficient in some of the above wheels.

PROF. H. M. HOWE:†—Steel and cast iron form two continuous and coterminous divisions of the iron-carbon series, the influence of carbon of course being modified by that of other variables. Now, I am confident that Mr. Outerbridge will see, on reflection, that it is not particularly reasonable to assume, as he seems to, that inferences about the constitution of one of these two divisions, drawn from our large store of knowledge of the constitution of the other, must necessarily be fallacious, and, therefore, to brush them aside without critical examination. The greater part of our reasoning in this world has to be by analogy, and the proper treatment, I had always supposed, of such reasoning was not to brush it aside as necessarily leading to false conclusions, but to examine its processes and test its products by comparison with known facts. That it needs the check of comparison with facts, as the case of manganese steel shows, by no means renders reasoning by analogy useless. It is, indeed, in my opinion, in large part because those interested in cast iron have failed to avail themselves of this mode of

* Mr. G. W. Beebe, *Iron Trade Review*, October 25, 1900.
† Communicated.

illuminating their subject that their knowledge is in its present unsatisfactory state, and he would be a narrow professor of metallurgy who, if an expert in so closely allied a subject as steel, should have no mature views on the constitution of cast iron. It appears to me that Mr. Outerbridge has offered neither evidence to rebut my conclusions, nor valid objection to my reasoning.

I have elaborated my views on this subject in a paper which will shortly appear in the *Transactions of the American Institute of Mining Engineers.*

In my original remarks I gave a reaction by which I suppose that sulphur is removed from cast iron in the blast furnace, by the reduction of lime, which, until so reduced, exists as lime silicate in the slag. For simplicity in stating the reaction I wrote to the CaO of the lime as if it were free, supposing that every reader would understand that this was my reason. To my surprise, a friend asks me if I think that the lime is free in the hearth of the blast furnace. Certainly not; it is the lime of the lime-silicate in the cinder that has to do with desulphurizing.

ELECTRICAL SECTION.

Stated Meeting, held February, 1900.

A FEW REMARKS ON X-RAYS AND OTHER RAYS.

By Arthur W. Goodspeed.

[ABSTRACT.]

I ought to ask your indulgence for the apparent lack of relation between the several topics which it seems to me not inappropriate to bring to your attention this evening. The avowed object of my friends in getting me here was to "help out," but judging from what I have heard and from what I see is to follow, you hardly need any assistance, so I will be as brief as possible.

In the first place, I would like to speak of a probable improvement in the inductorium as an X-ray generator, suggested by my own experience and subsequent measure-

ments. This matter was referred to more at length in an article by myself, "On the Technic of X-Ray Work," in the *Philadelphia Medical Journal*, January 6, 1900. A quotation from the article makes clear my point:

"Difficulty is often met in adjusting the interrupter for different rates on account of the sparking which results. In this case the capacity of the condenser is probably not suited to the set of conditions that must be met. In other words, the time of a complete cycle of operations, and the ratio in which this period is divided between closed and opened circuit in the primary, is of considerable importance, and is clearly related to the self-induction of the coil and the capacity of the condenser intended to take up this extra current. If the capacity be too small the condenser will be only partially effective, and sparking will result at the break.

"Adjustments should be made so that the actual interruption of the primary current shall be as sudden as possible. This results in a rapid variation in the magnetic flux through the iron core, which induces in the secondary a rapidly increasing electromotive force. This act of breaking the primary, however, produces a self-induction in the coil, which in itself tends to retard the suddenness of the break by causing an arc across between the points as they recede from each other. It seems as if the current possesses a sort of momentum, on account of which it becomes most difficult to stop the flow instantly. If, however, a condenser of large capacity be connected around the break, the extra current will flow into that. The condenser evidently must be of capacity sufficient effectively to absorb all the charge that would otherwise tend to jump between the contact points. But a very important part of the phenomenon is yet to follow. The best iron core will not alone lose its magnetism except after a time which is considerable when compared with intervals of the minute order of magnitude we are contemplating. To effect this necessary result the condenser at once discharges back through the circuit, the effect being to demagnetize the core very rapidly, thereby inducing an enormous electromotive force in the secondary.

"I am told by the makers that on the largest commercial X-ray coils the condenser capacities vary from 5 to 15 microfarads. A hasty measurement of the one I am using shows its capacity to be about 35 microfarads. To me this comparison suggests that the ordinary commercial coil would be much more efficient if its condenser were several times larger than usually made. If a coil with an insufficient condenser be operated slowly, it sparks badly at the break for reasons already given. If the speed be increased until the sparking is a minimum, it is so because the time of 'make' has been too short to allow the direct current to attain a maximum; the extra current due to self-induction is therefore less, and the small condenser can take care of it. Obviously, though, under these conditions the coil is not operating with maximum output. The time of 'make,' *i. e.*, the interval during which the primary is closed, ought to be just long enough to enable the current to reach its maximum value; this time, of course, depends on the self-induction of the coil as well as on its resistance. The time of 'break,' *i. e.*, the interval during which the circuit is open, must be long enough to enable the condenser to be charged and discharged. If the make follow the break too soon, clearly the direct current will interfere with the discharge of the condenser."

I will now pass around a few pictures illustrating some of the more recent interesting cases that have come to my attention in which X-ray examination has proved of very great assistance. (The pictures were passed, one at a time, preceded by a few words of explanation in each case.)

Another matter that it seems appropriate to bring before you this evening concerns the claims of priority in making the first electrographs by exposing a photographic plate directly between the poles of an electric machine and allowing the spark to produce its autograph. I noticed recently (see the *American X-Ray Journal*, December, 1899, p. 675) "that Dr. Wagner was the first person to get the impression by placing the sensitized plate between the sliding electrodes of a static machine." The short article from which I quote called forth in the next issue of the same journal (January,

1900, p. 693) a letter to the editor from Elmer Gates, claiming to have preceded Dr. Wagner by several weeks or more.

It really seems hardly worth while for these two gentlemen to dispute priority in taking electrographs, since your speaker, in connection with W. N. Jennings, of Philadelphia, made electrographs as early as November 20, 1889, in precisely the method described by Gates. Experiments along this line were conducted at intervals from 1889 till 1893. Electrographs of coins similar to those described in Thompson's book on X-rays, p. 19, were made by Jennings and myself on February 20, 1890. I am told that Kinraide, of Boston, several years ago showed some beautiful electrographs at the Franklin Institute, and I have not the least doubt that a dozen other experimenters performed the same experiments anywhere from five to ten years ago. Whether this be true or not, of the cases cited I have personal knowledge.

Upon one other point will I say a few words—one which is exciting considerable interest at this time among both chemists and physicists. I refer to the radiation emitted by the recently discovered radioactive substances obtained from uraninite. Early in 1898 Mme. Curie called attention to the fact that certain uranium minerals, as pitchblende, emitted Becquerel rays even more actively than uranium itself, and suggested the presence of a new substance to which this action is due. Later she and her husband isolated a new material much resembling bismuth and 400 times more active than uranium. To this substance they gave the name polonium, from Poland, their native country. Continued research upon pitchblende brought to light another substance very like barium, which at last proved to be 900 times more active than uranium. To this they gave the name radium. I have a developed photographic plate here which was exposed for several hours to the action of six little piles of uraninite, under each of which was a small piece of sheet metal about 0·005 centimeter thick. The metals were aluminum, lead, silver, gold, zinc, copper, and the plate shows roughly a difference in translucency—the aluminum seeming the least resistive, while perhaps the

lead is most so. This suggests a close relation, perhaps identity, with the X-rays. Recently the Curies are said to have separated still a third radioactive substance from pitchblende.

ERRATA.

ART.: "Fire Hazards." Parsons.

Page 173, paragraph 3 should read:

The total amount of risks in force in the United States by United States fire insurance companies and by branches of foreign companies transacting business in the State of New York, on December 31, 1898, amounted to $19,937,-661,137. The average premium was about 90 cents on each $100 of risk. The fire losses paid during that year were $71,785,247.

ART.: "Movements of Ground Water." Lyman.

Page 287, line 4; "cut," should be "cut. A linear mile could therefore yield to the cliff or cut."

Page 298, line 19 from bottom, "large" should be "larger."

Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, November 21, 1900.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 21, 1900.

President JOHN BIRKINBINE in the chair.

Present, 124 members and visitors.

Additions to membership since last report, 19.

The President, in a brief address, called the attention of members to the reception to be given by the Board of Managers to the members and friends of the Institute on Saturday evening, December 8th. He called attention to the fact that a feature of the evening would be an interesting series of novel exhibits and lecture-room demonstrations under the direction of the several Sections, and that a special effort would be made to arrange a choice photographic exhibit.

Prof. F. Lynwood Garrison gave, by request, an account of a recent professional trip to Northeastern China, with some remarks on the mineral re-

sources of the Chinese Empire. He dwelt especially on the immense deposits of coal of excellent quality occurring in various parts of that country, and referred incidentally also to the occurrence, in more or less abundance, of salt, petroleum, iron, antimony and quicksilver. None of these mineral riches had as yet been worked, except in the crudest and most superficial manner, and the speaker predicted that their systematic exploitation, which must come in the immediate future, would inaugurate an industrial revolution in the far East of vast importance to the whole civilized world. Prof. Garrison's remarks were freely illustrated with lantern views.

Mr. A. S. Hamilton, of Rochester, N. Y., exhibited and described the "Standard voting machine," which is now in legalized use in a considerable number of cities and towns throughout the country. The speaker showed the *modus operandi* of the machine, and gave a demonstration of its capabilities for the service for which it is designed. The subject attracted much interest, and some discussion followed its presentation.

The Secretary exhibited and made some running comments on a series of lantern views of the buildings and grounds of the Pan-American Exposition to be held in Buffalo, N. Y., from May 1 to November 1, 1901.

The meeting thereupon adjourned.

WM. H. WAHL, *Secretary.*

COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of proceedings of the stated meeting held Friday, October 12, 1900.*]

MR. H. R. HEYL in the chair.

(*Concluded from p. 398.*)

(No. 2090.) *Improvements in Steam Injectors.*—Strickland L. Kneass, Philadelphia, Pa.

ABSTRACT.—The improvements in question are the subject of several patents granted to applicant.

United States patent No. 376,315 (January 10, 1888) describes a form of construction of a steam injector which shall be automatic in its action under variable conditions of water supply and steam pressure, and which shall be capable of restarting itself if, for any cause, the jet should be broken, as soon as the disturbing cause is removed.

The practical results of this improvement are to make the injector automatic under widely-varying steam pressures, to enable feed-water of higher temperature to be handled, and to vary the range in quantity of water to a greater extent than was possible without this improvement.

The second improvement consists in an adjustable overflow casing large enough to permit of automatic restarting, and arranged in such a way that

the direction of the overflow discharge may be adjusted to suit the requirements of the position of the instrument.

The third improvement is for the purpose of increasing the quantity of water that can be supplied by an injector of a given size, or to increase the limiting pressure at which the maximum quantity of water can be supplied to a boiler. In other words, when an injector is taking the maximum quantity of water that can be supplied to it by the lifting discharge nozzle, the improvement is to open an additional passage through which water is supplied to the forcing nozzle.

A fourth improvement relates to the provision of an automatic valve for increasing the limiting pressure.

For the mechanical details of these several devices, reference is made to the following United States patents, viz.: No. 375,315 (January 10, 1888), No. 501,464, July 11, 1893; No. 541,620, June 25, 1895; and No. 625,267, May 16, 1899.

The committee refers to the results of several independent series of experiments made on injectors embodying the first three of these improvements, together with those made on corresponding injectors of other forms. In detail the injectors were self-starting and restarting under all the conditions of the tests, which was not the case with any others not embodying these improvements.

The range of operation was greater with this injector than with any other tested; that is, for any given pressure a certain maximum quantity of water could be delivered. The least quantity which could be delivered for the same pressure was less, and the range of operation greater with this than with any injector not using the same features.

The experiments showed also that by the use of the automatic valve for increasing the limiting pressure, the quantity of water continuously increased up to the highest pressure of these experiments (200 pounds). Certain other injectors tested had this same advantage, but none of them was restarting.

Under practical conditions, when discharging the maximum quantity of water this injector required the least quantity of steam per pound of water delivered, and it is therefore particularly valuable where the demand for steam is unusually heavy, and where it is necessary at the same time to put water into the boiler.

On the contrary, at low rates of delivery this injector requires more steam per pound of water delivered than several others, and the discharge temperature is therefore higher.

The report states the conclusion that the improvements here considered are of real value, and recommends the grant to applicant of the John Scott Legacy Premium and Medal. [*Sub-Committee.*—H. W. Spangler, Chairman; Hugo Bilgram, Francis Head.]

(No. 2127.) *Typewriting Machine.*—Remington-Sholes Company, Chicago. (Referred by the Jury of Awards of the National Export Exposition.)

ABSTRACT.—This machine is the subject of eight letters-patent of the United States, to which reference is made in the report.

The machine is described in the report as an improvement in details generally, with a few new features, over those previously known and used. (For

mechanical details, reference is made to the text of the report and to the patents filed in the case.)

The report concludes substantially as follows: Without making a summary of the various kinds of work which a typewriting machine is required to perform, we believe that on general work this machine will work as well, probably better, than other machines and that the improvements in details have added to its usefulness. It is an advance in the art and worthy of recognition because of its merit. The Edward Longstreth Medal of Merit is awarded to the inventors. [*Sub-Committee.*—J. Logan Fitts, Chairman; Luther L. Cheney, Geo. S. Cullen.]

Hydraulic Air Compressor.—Continental Compressed Air and Power Company, Philadelphia.

(Referred to the committee by the Bureau of Awards of the National Export Exposition.)

ABSTRACT.—The Committee reports that in order to determine the commercial utility of this invention it would be necessary to institute an elaborate series of tests for which no facilities are at present available. [*Sub-Committee.*—W. L. Simpson, Chairman; Wm. Copeland Furber, Coleman Sellers, Howard Rippey, John E. Codman]

(No. 2136.) *Typewriting Machine.*—George C. Blickensderfer, Stamford, Conn.

(Referred by the Bureau of Awards of the National Export Exposition.)

ABSTRACT.—This machine is the subject of a number of letters-patent of the United States to applicant, copies of which are filed with the application, and to these reference is made for description of mechanical details.

The machine under investigation is of the type wheel, direct-inking and printing class.

After detailing *seriatim* the capacity of the machine for meeting the various requirements expected of a machine of its class, the report concludes with the statement that the combination of parts in the instrument is novel, that it appears to be in a class by itself, and to represent an advance in the art of constructing typewriting machines; for which reasons the award of the John Scott Legacy Premium and Medal is recommended. [*Sub-Committee.*—J. Logan Fitts, Chairman; Luther L. Cheney, Geo. S. Cullen.]

(No. 2144.) *Station Potential Indicator or Compensator.*—Ralph D. Mershon, New York.

Reserved for publication in full.

The award of the Scott Legacy Premium and Medal is recommended to the inventor. [*Sub-Committee.*—W. M. Stine, Chairman; Charles C. Heyl.]

The meeting adopted a report on the protest of George A. Lowry, objecting to the award of the Scott Legacy Premium and Medal to Magnus Swenson for his invention of a round-lap cotton baling press. The report reaffirmed the committee's original conclusions, and the protest was accordingly dismissed.

W. H. W.

[*Abstract of proceedings of the stated meeting held Wednesday, November 7, 1900.*]

MR. H. R. HEVL in the chair.

The following reports were adopted:

(No. 2074.) *Electric Meter.*—Wm. D. Marks, Philadelphia.

ABSTRACT.—An intelligible description of this apparatus is impracticable without the use of sectional illustrations. For the detailed mechanical construction and *modus operandi*, reference is made to the contents of the file wrapper of the case. The report concludes that "the apparatus is durable, commercially accurate at moderate and high loads. It would probably not be quite satisfactory to the consumer and the supply company at very low loads." [*Sub-Committee.*—H. W. Spangler, Chairman; Carl Hering, A. W. Schramm, Arthur J. Rowland, Francis B. Crocker, Wm. A. Anthony.]

(No. 2131.) *Gasoline Vapor Lamps.*—The International Heat and Power Company, Philadelphia.

ABSTRACT.—This subject was referred to the Committee by the Bureau of Awards of the National Export Exposition.

The lamp is of the class which uses gasoline vapor burned with a Bunsen flame, under a Welsbach or other mantle of rare earths, which is thereby heated to brilliant incandescence. The light is of very high intensity—650 candles—and recent tests show the consumption of gasoline to be .35 quart per lamp per hour. Only one mantle is used in a lamp. The lamp is adapted for out-of-door service only.

The lamp is made to be enclosed in an ordinary street lantern, the gasoline tank being placed around the top of same, and when filled is made air-tight. The gasoline is fed to the burner by a tube leading from the tank, and a second tube leads down to a vessel below the lantern, in which is contained air under about 25 pounds pressure. The burner proper and generator have much the same relation as in other mantle lamps. Part of the heating flame is directed through auxiliary openings (gauze covered) against a double tube of copper lined with German silver. This is the generator in which the gasoline is vaporized. This vapor is then carried down to the base of the lamp and through a very small opening is forced up by the air pressure into the body of the burner, drawing air in with it, thence passing upward past a baffle-plate through gauzes and under the mantle, where it burns in a Bunsen flame. The lamp burns well at all atmospheric temperatures, in all kinds of weather, and is readily lighted.

This lamp differs from others of its class in that the vaporizer is detached from the burner proper and encircles it in a tube; in the absence of a needle valve to control the gasoline passing through the lamp; in the absence of packing in the tube delivering the gasoline; and in the arrangement of the baffle-plate below the mantle, to prevent the blast of air and gasoline vapor from destroying the mantle.

In these specifications this lamp is singular, and all are considered to be important. The general principles on which the operation of the lamp depends have long been known and used, and the only claims to originality reside in the judicious combination of parts used.

In recognition of the improvements embodied in this lamp, the Committee awards to the International Heat, Light and Power Company the Edward Longstreth Medal of Merit. [*Sub-Committee.*—Arthur J. Rowland, Chairman; Moses G. Wilder, Frank P. Brown, Wm. McDevitt, Charles A. Hexamer.]

Passed first reading:

(No. 2122.) *Reconstructed Granite.*—The Reconstructed Granite Company, Norristown, Pa. (Referred by the Bureau of Awards.)

(No. 2133.) *Canned Ice.*—The Misko Canned Ice Company. Dismissed for want of needful data.

W. H. W.

SECTIONS.

Abstracts of Proceedings.

CHEMICAL SECTION.—*Stated Meeting*, held Thursday, October 25, 1900. Dr. W. J. Williams in the chair.

Dr. Joseph W. Richards, of Bethlehem, Pa., read a paper "On the Utilization of Blast-furnace Gases in Gas Engines." (Published in full in the *Journal* for December.) W.

SECTION OF PHOTOGRAPHY AND MICROSCOPY.—*Stated Meeting*, held Thursday, November 1st. Dr. Henry Leffmann in the chair.

The evening was devoted to the subject of "Motion Pictures." Several members contributed illustrations of earlier forms of motion pictures. Among others, the early work of Muybridge in this field was specially referred to. Some of the modern methods were well illustrated by exhibits made by Lubin, of Philadelphia, and Jenkins, of Washington. A general discussion followed on the scientific applications of the modern methods.

F. M. SAWYER,
Secretary.

MINING AND METALLURGICAL SECTION.—*Stated Meeting*, held Wednesday, November 14th. Mr. Joseph Richards, President, in the chair.

The paper of the evening was read by Prof. F. Lynwood Garrison, entitled "Notes on the Mineral Resources of China."

MECHANICAL AND ENGINEERING SECTION AND ELECTRICAL SECTION.—Proceedings of the joint meeting held Thursday, November 16th. Mr. John F. Rowland, Jr., President of the Mechanical and Engineering Section, in the chair. There were present 98 members and visitors.

The subject for discussion was "The Electrical Distribution of Power in Workshops." The subject was opened by Prof. F. B. Crocker, of Columbia University, New York, who gave a brief sketch of the history of the development of the electric motor and exhibited on the screen a number of typical

cases showing the application of electric power for driving machine tools, printing presses and miscellaneous machinery. He enumerated the salient advantages of electric driving over the use of steam-driven line shafting.

Mr. Samuel M. Vauclain, superintendent of the Baldwin Locomotive Works, Philadelphia, gave an interesting and instructive account of the experience with the introduction of electric driving in the Baldwin Works. He gave an account of the early difficulties encountered, and of how they were at length successfully overcome. He gave a cordial endorsement of the great advantages derived from the use of the modern method.

Mr. W. H. Tapley, of the Government Printing Office in Washington, followed in similar vein, setting forth in some detail the great advantages in convenience, saving of space, and economy derived in that office from the adoption of the electric driving of the Government presses.

Mr. Gano S. Dunn, of the Crocker-Wheeler Company, spoke at some length on the limitations of the electric motor, and on the problems for the future development of the apparatus.

Dr. A. E. Kennelly, Messrs. Chas. J. Dougherty, W. C. L. Eglin and Carl Hering also contributed interesting remarks and comments. Mr. Hering dwelt specially on the relative merits of the direct and alternating current motor, claiming that the latter possessed decided advantages over the former type. Mr. Dunn took the floor in answer to Mr. Hering, claiming that in many important features the direct-current apparatus was superior to the other type.

The meeting was then adjourned.

RICHARD L. BINDER,
Secretary.

CHEMICAL SECTION.—Proceedings of the *Stated Meeting* of Thursday, November 22d. Dr. W. J. Williams in the chair. Present, twenty-four members and visitors.

Dr. Henry Leffmann read the paper of the evening, on "Methods of Micro-Chemical Analysis." The subject was freely illustrated. The paper was discussed by Dr. Meeker, who also made some interesting remarks on the "Centrifuge," with especial reference to the use of the instrument in the estimation of manganese in iron. The meeting passed a vote of thanks to Dr. Leffmann for his instructive communication, and adjourned.

W. E. RIDENOUR,
Secretary.